CANAL SYSTEM

Mission Bay
San Francisco

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Mission Bay

Canal System Special Study

I. INTRODUCTION

This Canal System study is one of about 20 Mission Bay Special Studies. The study presents an analysis of environmental design opportunities and constraints in tne creation of a salt water canal system within Mission Bay. The study discusses the pros and cons of alternative construction modes for salt water canals soutn of the existing tidal China Basin Channel, if one were developed as part of the open space system. The study also assesses the type of design measures that might be required to improve circulation and flushing in the China Basin Channel. The purpose of this study is to identify the comparative merits of a fixed water level versus tidal canal, and soft versus hard edges to a new canal in Mission Bay. The type of canal system and its edge treatment that could be proposed for Mission Bay should not be interpreted as one proposal versus another but, rather, as a possible combination of canal systems and edge treatments that can be used where appropriate within the site. Hard-edge bank treatments may be appropriate in some places, soft edges in others. In addition to fixed water level and tidal canals, a partial tidal canal may be appropriate.

Early on in the Mission Bay planning process the concern was raised that sewer outflows in the western end of China Basin Channel may constitute a problem with regard to water quality either for the existing Channel or for the proposed development at Mission Bay. Staff of the City's Clean Water Program equate the about eight expected annual storm overflows after system improvements are completed to discharge of better than primary treatment quality. They also suggest deferring any decisions until the results of improvements now underway are complete. Thus water quality may not be as significant a problem as is expressed in the consultants' reports within this study. Another special study, Sewage Overflow Options, addresses this issue in more detail.

The consultants' reports include a concept of modifying the western end of China Basin Channel to maximize its flushing capability. This can be addressed further, if appropriate, after additional information becomes available about the reduced number of sewage overflows within the Channel.

This study gathers and analyses information from five consultants' reports and each report is included in a section numbered as follows:

III. Preliminary analysis of Environmental Design Opportunities and Constraints in the Creation of Soft Water Loop Channel Systems within the Mission Bay Project, by Danadjieva and Koenig Associates.

An analysis and summary of the reports noted below.

IV. SOURCES AND CAUSES OF ODOR PROBLEMS IN THE SAN FRANCISCO BAY AREA with special concern to the potential for odor problems at the Mission Bay Open Space Element: Wetland creation, by Wetlands Research Associates, Inc.

A discussion on the potential for odor problems to develop from mudflats or soft bank edges created as part of Mission Bay and implications for the design of wildlife habitat.

V. MISSION BAY CANAL ALTERNATIVES, by KCA Engineers, Inc.

An evaluation of four possible canal construction alternatives for Mission Bay.

VI. GEOTECHNICAL AND EARTHQUAKE ENGINEERING CONSIDERATIONS OF FIXED LEVEL AND TIDAL CANALS AT MISSION BAY, by Dames & Moore.

An evaluation of the geotechnical engineering factors for Mission Bay.

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VII. PRELIMINARY ANALYSIS of a CIRCULATION DESIGN FOR MISSION BAY, by Philip Williams & Associates.

An assessment of design measures for improved circulation and flushing in the China Basin Channel and discussion on a looped channel construction.

The reports mentioned above have also been useful in other special studies related to a canal system proposal. In particular, the Sewage Overflow Options, Infrastructure Costs and the Wetlands/Playfields special studies have taken into account such factors as odor problems of sewage overflow, water quality and circulation, water features and their size requirements, and water edge treatments referred to in the Canal System Special Study.

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1986.

II. SUMMARY

This Canal System study is a Mission Bay Special Study. It presents an evaluation of four possible canal construction alternatives for Mission Bay with either fixed level or tidal canal construction methods. The edge treatments could be hard or soft; however, the hard edge is favorable for hydrologic efficiency; i.e., facilitating water flow. The fixed level system is analyzed under three flow variations according to channel depths and pumping systems used. All configurations entertain construction of a new loop channel from the vicinity of Mission Rock to the western end of China Basin Channel. Although the scale of the canal system, if not developed with improved water quality as a major function, may be smaller than what is suggested in the consultants' reports.

Tidal vs. Fixed Level/Hard vs. Soft Edge

The four canal alternatives evaluated were: 1) Fixed Level Canal/Soft Edge; 2) Fixed Level Canal/Hard Edge; 3) Tidal Canal/Hard Edge; and 4) Tidal Canal/Soft Edge. Edge refers to the type of canal bank treatment. A hard edge is based on structural support for the banks and a soft edge on a natural slope which would not be eroded and thus undermined by water flow. The hard edge can be landscaped to appear natural.

The Philip Williams & Associates, the Danadjieva and Koenig Associates and the KCA, Engineers reports do not consider the Tidal Canal/Soft Edge system as a viable alternative for Mission Bay. The reports state that it poses serious constraints from a standpoint of aesthetic design, safety, potential odor problems and space consumption. The Tidal Canal/Hard Edge system would limit its amenity value to the community requiring the mean low water level to be over 10 feet below grade.

The Danadjieva and Koenig Associates report describes the merits of the Fixed Level systems and different velocities in detail in terms of space requirements, initial construction costs and annual maintenance. In all cases the Hard Edge requires a much reduced width than the Soft Edge treatment. In

terms of low or high velocity of flow the greatest flexibility is offered by the high velocity system because it is fully-lined with a concrete bottom. However, initial construction costs in the Fixed Level, high velocity option will be greater than for the low velocity because of the concrete bottom However, the difference would be offset by the lesser excavation costs, lower maintenance costs and greater flexibility for the Fixed Level, high velocity option. Design opportunities are also discussed for the three Fixed Level alternatives, 1A) Soft Edge; 1B) Low Velocity, Hard Edge and 1C) High Velocity, Hard Edge.

VIII. Implications for Mission Bay

A canal system concept will be considered as a possible water/open space feature for the open space element of the Mission Bay Plan.

From the standpoint of development phasing, any loop canal system would likely require more infrastructure costs at the outset, in order to complete the canal in one construction period. Water levels in a canal could increase the ground water level in surrounding areas, particularly for a fixed level canal with a water surface near the ground surface. This rise in the water table could be reduced or eliminated through use of a structurally hard system to contain the canal waters. Any such changes in ground water level would not significantly increase the liquefaction potential in surrounding areas. The special study on Infrastructure Costs includes estimates for canals.

From the standpoint of design and aesthetics, the addition of a new loop channel, fixed, tidal or any combination, could provide a visual and recreational amenity to the Mission Bay community. The soft edge option requires the most space particularly for the channel depth required for full tidal flow. However, it might have applications for some areas within Mission Bay to provide a degree of variety to the overall design. A wider range of landscaping can be provided with a structurally hard edge to reduce salt-water intrusion into planting areas.

From the standpoint of applicable policy and governmental jurisdiction, the construction of a tidal canal system with unimpeded, free tidal action would expand the jurisdiction of the San Francisco Bay Conservation and Development Commission (BCDC) under its 100 feet shoreline jurisdictional powers. However, if a tidal control structure such as a pumping station or flap gates are constructed between the Bay and the inland canal, then BCDC's jurisdiction would not apply to the inland canal.

ASB/20

Danadjieva & Koenig Associates
Environmental Design:
Architecture Planning Urban Design

Angela Danadjieva
Urban Designer
Thomas R. Koenig, AIA
Architect Planner

III. PRELIMINARY ANALYSIS OF ENVIRONMENTAL DESIGN OPPORTUNITIES AND CONSTRAINTS IN THE CREATION OF SALT WATER LOOP CHANNEL SYSTEMS WITHIN THE MISSION BAY PROJECT

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INTRODUCTION

Based upon analyses presented in the following papers:

1. SOURCES AND CAUSES OF ODOR PROBLEMS IN THE SAN FRANCISCO BAY AREA with special concern to the potential for odor problems at the Mission Bay Open Space Element: Wetland creation, by Wetlands Research Associates, Inc., January 1986.

2. MISSION BAY CANAL ALTERNATIVES, by KCA Engineers, Inc., February 13, 1986.

3. GEOTECHNICAL AND EARTHQUAKE ENGINEERING CONSIDERATIONS OF FIXED LEVEL AND TIDAL CANALS AT MISSION BAY, by Dames & Moore, February 14, 1986.

4. PRELIMINARY ANALYSIS OF A CIRCULATION DESIGN FOR MISSION BAY, by Philip Williams & Associates, February 25, 1986.

the purpose of this working paper is to present a statement of the problem(s) which may predicate the construction of a salt water channel system within Mission Bay, a brief description of the alternatives being considered, an analytic discussion of environmental and aesthetic design implications of each alternative and a summary of conclusions and recommendations.

PROBLEM STATEMENT

There is concern that sewer outflows discharging into the upper end of China Basin Channel may constitute a problem with regard to water quality. While a precise determination of the water quality problems is not available at this time, from the perspective of the proposed development at Mission Bay, impacts on aesthetics and odor are perceived to be significant potential problems.

Two strategies have been advanced for improving water quality in the Channel:

- Elimination of the sewage discharges;

- Improved circulation to flush out sewage as quickly as possible.

Elimination of discharges requires moving the discharge point or building sufficient storage to contain overflows.

Three methods for improving Channel circulation include:

a. Modifying the existing channel geometry to maximize tidal flushing.

b. Construction of a new tidal channel linked to the end of China Basin Channel to create a net tidal circulation.

c. Providing a pumping system to discharge clean Bay water into the upper end of the Channel.

Method "a" appears to be a worthwhile endeavor in any case and should be considered in addition to method "b" or "c". Basically it would entail maintaining the upper channel in a broader and shallower configuration to maximize the tidal prism and thus the flushing capability. The focus of this report will be on methods "b" and "c" as the options which will have strong aesthetic design implications to the Mission Bay project.

One option within method "c" is simply a pressurized underground pipeline which would deliver clean Bay water from a pumping station near south of Pier 54 to the upper end of China Basin Channel. It would be operated only a few times each year when water quality problems in the Channel occurred. This system would have no aesthetic design implications to the project and therefore will not be discussed further in this report.

For discussion purposes, we will refer to method "b" as the TIDAL SYSTEM and method "c" as the FIXED LEVEL SYSTEM.

TIDAL SYSTEM

The principal behind this system is to use tidal energy to pump water into the upper end of China Basin Channel during the ebb tide cycle. This is done by constructing a new loop channel from the vicinity of "south of Pier 54" to the upper end of China Basin Channel. Tide gates would be placed at the Bay end to allow inflow during the flood tide only. Another set of tide gates would be placed at the western end to allow discharge during the ebb tide into China Basin Channel while preventing sewage discharges from backing into the tidal channel. It appears that the feasible length of this loop channel is approximately 4000 feet with a range in width from 30 to 140 feet. It would have a full tidal range (high water to low water), the same as in China Basin Channel and the Bay.

Edge treatment could be hard or soft although walls or steeper

slopes are hydrologically more efficient than the shallower natural edges. The soft edge system would also require a significantly wider channel for a given water volume than the hard edge system. The issue of hard vs soft edges will be discussed in detail later in this paper.

FIXED LEVEL SYSTEMS

The principal here is to pump clean Bay water in an open channel from around south of Pier 54, some 4000 to 5000 feet to the upper end of China Basin Channel. Three variations on the theme include (1) a low velocity continuous flow, (2) a low velocity varying flow and (3) a high velocity continuous flow. These imply average channel depths of 6 feet, 10 feet and 4.7 feet respectively and vary somewhat in pumping systems used. The high velocity continuous system would suggest, because of its lesser water depth, a lined channel to allow for cleaning.

From an aesthetic design point of view, the fully lined system has some very positive implications which will be discussed later. For the most part, however, all three variations can be discussed as a group under the heading of Fixed Level. They can accommodate hard or soft edges aesthetically, however, the hard edge is favored for hydrologic efficiency.

ENVIRONMENTAL AND AESTHETIC DESIGN IMPLICATIONS

If an added loop channel system is employed to deliver Bay water to the upper end of China Basin Channel, it would significantly improve circulation while providing a valuable visual and recreational amenity to the Mission Bay community. The thrust of this report is to analyze the aesthetic and environmental design opportunities and constraints inherent in each of the loop channel systems being considered, including hard edge vs soft edge treatments, tidal vs fixed level, channel configurations, planting and paving considerations and responses to hydrological, geotechnical, structural, space utilization, potential odor, public safety, maintenance and cost issues. The approach will be deductive in that it will eliminate various alternatives when sufficient adverse factors, or lack of positive ones, become apparent.

Discussion of edge conditions along a loop channel system has included the terms "hard" edge and "soft" edge. These have been used sometimes to refer to the general appearance, hard being more urban and paved and soft being more planted and natural, and other times to refer to the structural character of the channel. The underlying use in this report is structural in that "hard" edge implies a confined channel, contained

to some degree by a built (concrete, steel, wood, etc.) structure in order to control width and depth and to provide a degree of separation between the salt water and surrounding land areas while "soft" edge suggests an earth-formed channel with slopes of approximately 5 horizontal to 1 vertical. Because the channel depth is a given, the minimum width, as a function of 5 to 1 earth slopes, must be considerably wider for soft edge than for hard edge configurations. Beyond that, "soft" vs "hard" edges are considered in the visual appearance sense.

It is possible to create soft appearing edges within the hard edge structural system with plantings and natural elements incorporated within the channel wall and, conversely, hard edge features may be constructed within the soft edge system to present a more urban appearance. This ability to combine various visual features within either hard or soft edge channel systems offers opportunities for developing a more varied and rich loop channel environment.

Inherent in the visual notion of "soft" edges is the element of plant material, particularly plantings close to the water's edge. The critical issue here is that of providing a barrier between salt water and tree roots, either by containing the water course itself or by containing the plantings. If we must confine the plant materials to those which are salt water tolerant, we severely limit the planting design palette. This is important because, while salt tolerant marsh plantings may be appropriate to salt water related environments (a full salt marsh plant ecology continues to be explored for the marsh habitat areas), the Mission Bay project is basically an urban environment with considerable space limitations and a need for a more varied landscape expression.

In the soft edge situation in which natural earth slopes, at approximately 5 to 1, form the channel, the implication is that trees be contained and secondary plantings be salt water tolerant as in a natural wetland setting. The costs involved in containment of a soft edge channel, particularly a wide tidal channel, may be prohibitive. The soft edge would therefore tend to be planted in a more sparse manner, with fewer trees and more shrubs. Maintenance costs would also tend to be higher due to salt marsh plants in urban areas where greater control is desired. While the soft edge treatment is recommended for the marsh habitat areas, its application to the loop channel system appears limited. Given the heights of surrounding buildings and the resulting shade patterns, it would be difficult to maintain salt marsh vegetation within the loop channel corridor.

The hard edge situation would suggest far more flexibility in plant material because of the containment of the channel itself.

This is particularly true of the high velocity continuous flow system because it would be a shallower, fully lined channel, providing a salt water barrier to the entire surrounding area. A full variety of plant material could therefore be used adjacent to the water's edge.

With respect to paving, ample opportunities exist for integrating walkways, steps, seating, lookouts, terraces, planters, platforms, etc. in either the soft or hard edge treatments. In the more confined corridors within the community, the hard edge situation would offer advantages over the soft because of lesser space requirements and narrower channel widths.

For variety, the system may have both hard and soft edges. If it were basically a hard edge system, there may be places which can, in fact, be natural and soft to contrast to the hard edge theme or serve as transitional elements toward the wetland habitat or waterfront park areas.

Tidal vs Fixed Level:

Far more important to the aesthetic design considerations is whether the system is tidal or fixed level. Some of the plans put forth by various groups within the San Francisco community have suggested tidal waterways within the Mission Bay development and therefore this option deserves special attention from many points of view. For the most part, these proposals have suggested tidal marshes of a more centralized nature such as a marsh wildlife habitat (still being explored for Mission Bay) rather than a loop channel system which is the focal issue of this report.

In the case of a loop channel, the tidal systems, both hard and soft edge, appear to have serious drawbacks. Hydrologically, both are feasible with hard edge favored for circulation efficiency. Construction considerations indicate that tidal systems are more costly than fixed level, particularly the hard edge, and in the soft edge case, in the need for extremely long bridges. Tide variations require a depth of about 14 feet and, with banks sloped at 5 to 1, the minimum channel width becomes 140 feet. Geotechnically, the shallower fixed level channels are superior to tidal channels from the earthquake perspective.

Potential odor problems are a greater concern with tidal channels than with fixed level because of the low tide levels which leave areas of mud flat or retaining wall, where algal growth is a natural phenomenon, exposed for significant periods of time. In fixed level systems, the constant water levels offer a much higher degree of control.

Perhaps the most overriding issue with tidal channel systems is the greater space requirement. The soft edge option, with its minimum width of about 140 feet, while appropriate to the centralized marsh habitat application, is less realistic over a 4000 or 5000 foot length, particularly within the dense urban environment proposed in current plans. While a hard edge tidal channel would consume far less space (similar to the fixed level hard edge options), it has no advantages over the fixed level systems. Paramount among its disadvantages are its significantly higher construction costs, the depth (at low tide) of water below grade which poses potential hazards to public safety, and its aesthetic design constraints.

In the case of the hard edge tidal situation, the mean low water level would be over 10 feet below grade, limiting the channel's amenity value to the community and exposing large bare walls. Attempts to respond to this system with stepped ledges or terraces, while offering amenity value, would tend to negate any space savings, may not eliminate the hazard to public safety, and would necessitate higher maintenance costs. All things considered (space requirements, public safety, cost and appearance), any tidal loop channel system would appear to be unfeasible for the Mission Bay project. The balance of this report will therefore be confined to Fixed Level loop channel alternatives.

Potential Odor Problems:

The subject of odor problems needs some general background discussion because of the subjectivity of the term. This is covered in detail in the report by Wetlands Research Associates, however, a brief summary would be helpful here.

Far and away, the larger odor problem is associated with the sewage outfall situation in China Basin Channel and the loop channel is aimed at mitigating that. Potential for offensive odors within the loop channel itself will mainly be associated with decomposition of algae and other plants. While growing, the algae do not produce problems, however, if they accumulate on shore and die (not such a likelihood with the fixed level channel), the bacterial decomposition can result in odor problems. Design considerations which would limit the occurrence of odor problems at Mission Bay are those which primarily reduce algal plant production and include:

- Maintaining continuous circulation in the channel.
- Maintaining salinities above 10 to 20 ppt to eliminate widgeon grass growth.
- Reducing nutrient loading from adjacent landscaped areas.

Finally, physical cleaning of the channel, if necessary, could be carried out. This would be most easily done with the fully lined, high velocity, continuous flow system in which the bottom is hard surfaced.

Fixed Level, Soft Edge:

The main issues with this system concern space requirements, decreased circulation along shallow edges which implies greater plant growth, and the limitations to planting design along the edges, discussed earlier. This option will require about 50% more land area than the hard edge alternatives (minimum 90 to 100 feet). It may be possible to reduce this width slightly. The Dames & Moore report suggests that 5 to 1 slopes may be conservative given the soils conditions at Mission Bay.

Current Mission Bay plan proposals suggest the need for efficient space utilization which does not favor the soft edge option for most of the channel length. Greater widths would also necessitate longer bridge structures at substantially higher costs. On the favorable side, investigations by KCA Engineers, Inc., indicate a lower relative initial construction cost for this system than for any other. This may be offset, however, by higher annual maintenance costs, initial costs for longer bridges and costs associated with the loss of valuable land.

Fixed Level, Hard Edge:

Three options are being considered within the fixed level, hard edge category, all of which offer advantages over the soft edge system. These are (1) low velocity, continuous flow, (2) low velocity, varying flow and (3) high velocity, continuous flow.

Low Velocity, Continuous Flow:

With this alternative, a pump station located in the south of Pier 54 area would continuously discharge into the loop channel which would flow westward, through the development, to discharge at the upper end of China Basin Channel. The channel would be about 30 to 100 feet wide and deep enough to prevent algal growth on the bottom (approximately 3 feet) with an additional 1 foot to allow for sedimentation. Allowing for about 2 feet of freeboard (this could possibly be reduced to 1 foot), the total channel depth would be approximately 6 feet. With this depth, the channel bottom need not be lined. It would be advisable to have vertical or steep banks to minimize shallow water areas where algae can grow. In this alternative the water level would be constant.

Low Velocity, Varying Flow:

A variation on the above is to release water from the channel into China Basin Channel only during the ebb tide. Releasing a given amount of water during the ebb is somewhat more effective in flushing pollutants than releasing the same amount of water continuously, and so the total amount of pumping required would be less than for the first alternative. In this operation, the channel acts as a reservoir being pumped full during the flood tide and discharged during the ebb. The water level would fluctuate about 4 feet, requiring a total depth of about 10 feet, allowing 2 feet of freeboard. Channel sides could be made vertical to minimize algal growth or, alternatively, gently sloped if a fringe of marsh vegetation were desired.

High Velocity, Continuous Flow:

In this alternative, a shallow, fast moving stream flowing through the development would discharge at the upper end of China Basin Channel by a pumping station near the south of Pier 54 area. For instance, if 20,000 gpm were determined to provide adequate flushing, then a channel flowing 1 foot deep and 20 feet wide would be sufficient and the total head loss over 4000 feet would be about 10 feet. This would probably require two booster pumps along the length of the channel, each lifting the water about 3½ feet, if deep excavations are to be avoided.

Typical velocities in the channel would be about 3 ft./second. This would prevent sediment accumulation and may be sufficient to prevent algal growth on the channel bottom. The channel would be lined to allow for cleaning and to serve as a barrier between the salt water and the adjacent landscaped areas. In addition, street runoff should be drained separately and not allowed to enter the channel.

In all cases a much reduced width is required than with the soft edge system, enabling more efficient use of land. In the case of the high velocity system, the width might be as little as 20 feet with an average depth of 4.7 feet, affording minimum excavation. From the standpoint of aesthetic design opportunities, the two low velocity options are fairly similar, therefore, subsequent discussion will differentiate only between high velocity and low velocity systems.

In the case of the low velocity option, geotechnical considerations suggest that sheet piles, should that system be employed, would have to be driven to a considerable depth below the bottom of the channel to prevent slope failures through soft mud (even for average soil conditions). In addition, it is likely that

the sheet pile walls would require anchors (or tiebacks) and a heavy structural section to prevent undesirable deflections of the wall. The KCA report suggests, with concrete walls, a lesser depth but substantial footings would be necessary. From a design point of view, concrete is preferred because of appearance and the flexibility in integrating planters, steps, walks, terraces, etc. in the same material.

An advantage with the high velocity option is that it is considerably shallower and could be narrower than the low velocity system. An important consideration which the KCA report points out is that in the excavation operation, if contaminated materials are encountered, removal of such materials to a class "A" dump site can cost $200 per cubic yard. This could increase excavation costs by a factor of 10. The shallower system is also superior from earthquake considerations. Another advantage is that it is fully lined with a concrete bottom so that walls and bottom form a rigid integrated construction. This system is most efficient hydrologically, is easiest to maintain and its full containment provides a relatively positive continuous barrier between salt water and all planting areas. Conversely, the barrier also prevents nutrient loading into the channel from adjacent landscaped areas.

As pointed out in the Dames & Moore report, the low velocity option, with soft bottom, could cause a significant increase in ground water levels (normally at about 6 feet below grade) within 50 to 100 feet of the channel, by establishing a water level within 1 foot of the ground surface and about 5 feet above the existing average water level. This higher water level in the fills would have the obvious disadvantage of placing some basement excavations below water level with the resultant increase in construction costs. On the otherhand, the fully contained, high velocity system would tend to negate these concerns.

It is important to point out the great flexibility offered by the high velocity system to the project, particularly over the long run. Because it is fully self-contained, it can be placed close to buildings, its structural integration is further enhanced by shorter bridges which serve as top ties across the channel, its impacts on adjacent construction are minimal, it requires the least amount of space and depth, it is the easiest system to clean and maintain and it allows the greatest flexibility in planting design.

Its shallowness and high water velocity provide maximum water circulation, better water quality, decreased algal buildup and higher amenity value while minimizing potential hazards to the public safety. In a word, the high velocity system is the most "controllable."

Relative Costs:

As clearly pointed out in the KCA report, relative construction costs are greater for the tidal loop channel systems than for the fixed level. Among the fixed level alternatives, the soft edge option is about half the cost of the hard edge, but this comparison is based on a soft edge channel width of 90 feet (which is the minimum feasible width) and a hard edge channel width of 60 feet. In the alternative plans being proposed for Mission Bay, the hard edge options envisioned are considerably narrower, say an average of 30 to 40 feet. This would suggest lesser costs for excavation and considerable savings in valuable space retained.

Initial construction costs for the fixed level, high velocity option will be greater than for the low velocity because of the concrete bottom, however, the difference would be offset considerably by the lesser excavation costs, lower maintenance costs in the long term, and the significant advantages afforded by flexible and efficient space utilization. As plans are developed in more detail, more refined cost analyses will be possible. These should consider initial construction costs in combination with long term maintenance figures as well as savings implications to adjacent development and overall space efficiency.

Design Opportunities:

Given that tidal loop channel systems, of any configuration, do not appear feasible for current Mission Bay plan proposals, discussion of design opportunities will be confined to three fixed level alternatives --- Soft Edge, Low Velocity Hard Edge and High Velocity Hard Edge.

Figures 1A, 1B and 1C illustrate relative cross section sizes.

Various opportunities are available for achieving a degree of separation between the salt water and areas to be planted including containment of the water body with a clay layer or a buried impermeable device (gunite, membrane, etc.) and/or containment of plantings, as well as drainage systems for planted areas. These are not necessary for the high velocity option because of the degree of control already provided by the fully lined channel. Trees may literally be placed anywhere.

Figures 2A, 2B and 2C illustrate some of these methods.

Paved surfaces, including concrete, brick, stone, wood or other applicable materials, in conjunction with planting

treatments offer a broad range of aesthetic design opportunities for edge and surrounding area treatments such as steps, plazas, walkways, terraces, platforms, planters, seating and sculpture. In addition to the obvious visual enhancement, these elements enliven the recreational character of the channel corridor and edges by offering a rich variety of human experience opportunities as well as a close physical relationship with the water.

Figures 3 through 7 illustrate some of the possible soft and hard edge treatments in combination with various planting opportunities inherent in each type of loop channel configuration.

Phasing:

With any of the loop channel systems, it would be best to complete the functional aspects of the waterway (the channel itself) in a single construction period so that the improvement to China Basin Channel circulation would be operational and to minimize inconvenience, noise and odor to Mission Bay residents. After that, however, construction of the edge treatment elements, plantings and adjacent open spaces could occur incrementally, in association with subsequent phases of the overall development. The loop channel open space corridor will provide strong imagery and identity to the Mission Bay project and its early completion may be beneficial to the project marketing effort.

RELATIVE CROSS SECTION SIZES

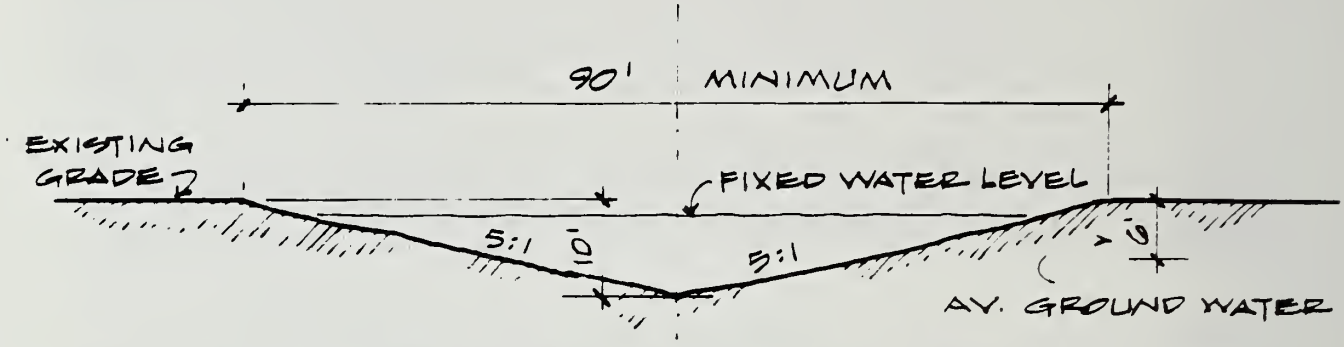

FIGURE 1A: FIXED LEVEL, SOFT EDGE

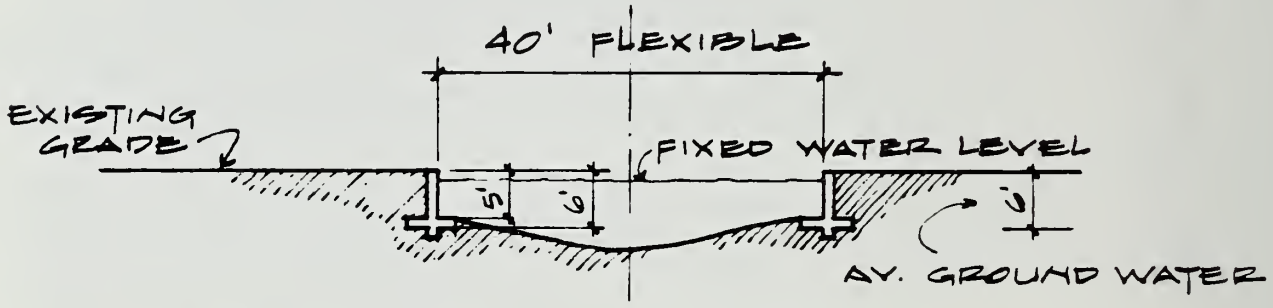

FIGURE 1B: LOW VELOCITY, HARD EDGE

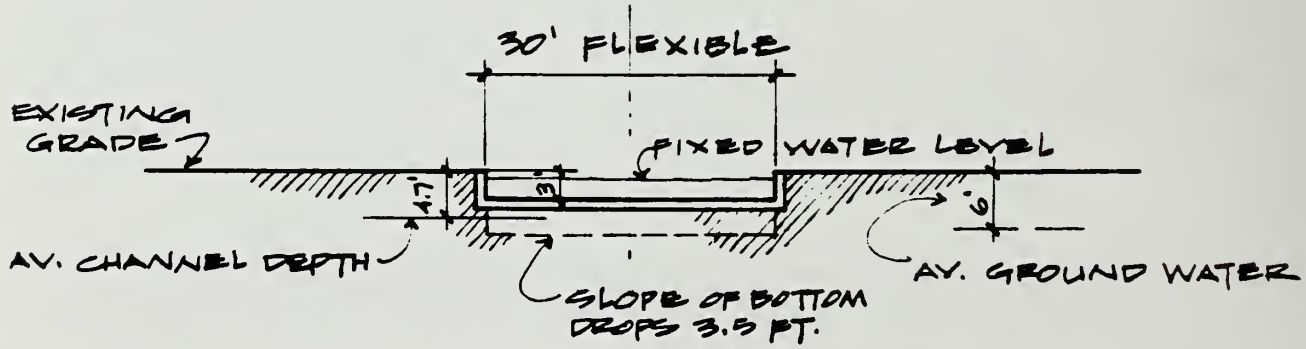

FIGURE 1C: HIGH VELOCITY, HARD EDGE

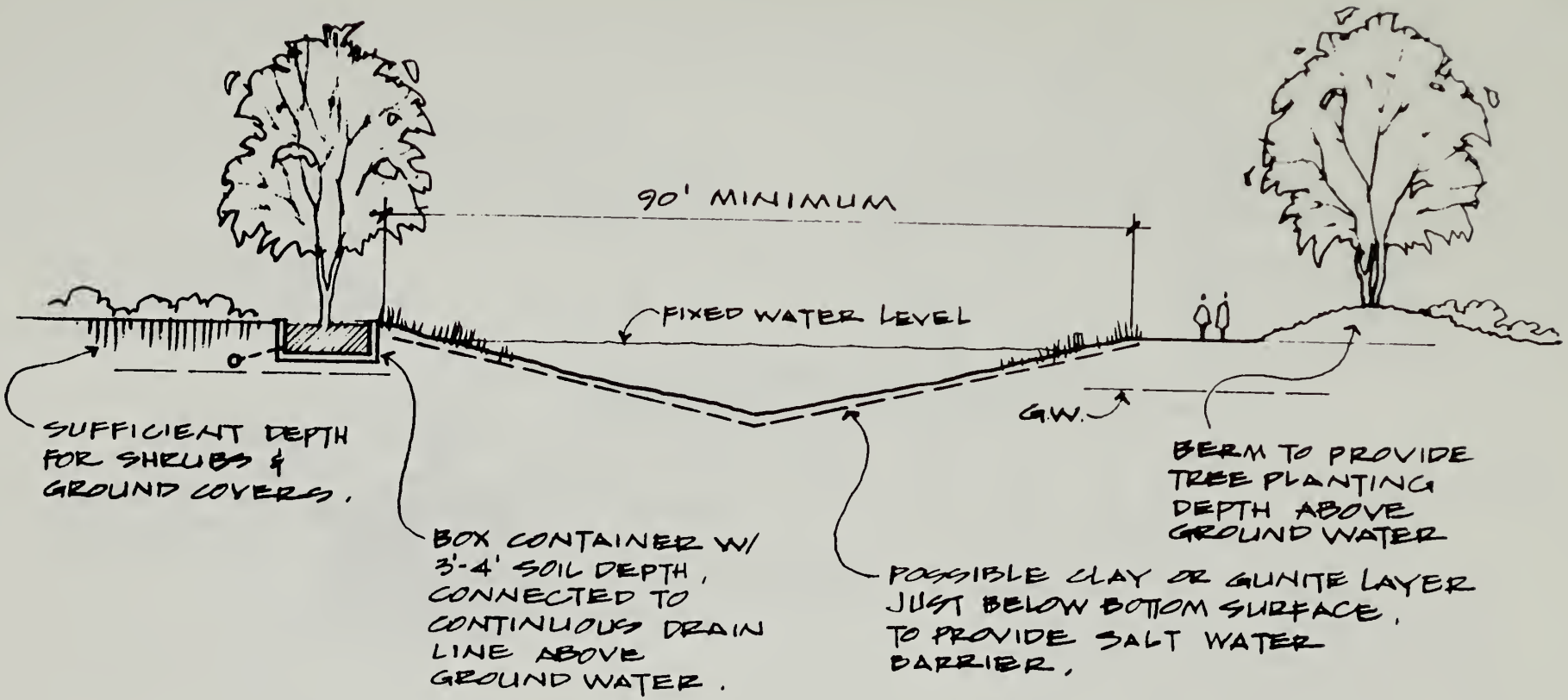
90' MINIMUM
FIXED WATER LEVEL
G.W.
SUFFICIENT DEPTH FOR SHRUBS & GROUND COVERS.
BOX CONTAINER W/ 3'-4' SOIL DEPTH, CONNECTED TO CONTINUOUS DRAIN LINE ABOVE GROUND WATER.
POSSIBLE CLAY OR GUNITE LAYER JUST BELOW BOTTOM SURFACE, TO PROVIDE SALT WATER BARRIER.
BERM TO PROVIDE TREE PLANTING DEPTH ABOVE GROUND WATER

FIGURE 2A: SOFT EDGE - BARRIER / TREE PLANTING / DRAINAGE

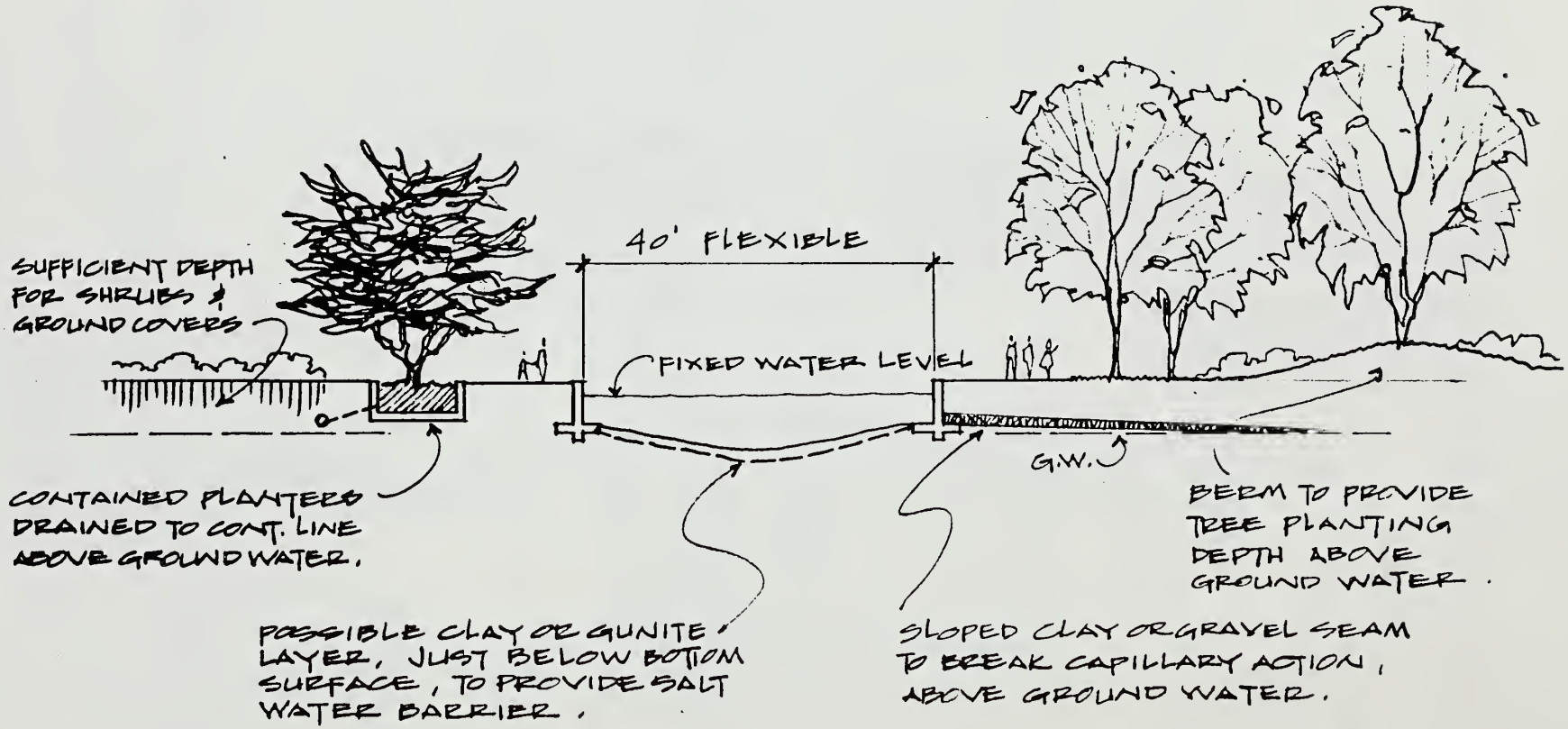
40' FLEXIBLE
SUFFICIENT DEPTH FOR SHRUBS & GROUND COVERS
FIXED WATER LEVEL
G.W.
CONTAINED PLANTERS DRAINED TO CONT. LINE ABOVE GROUND WATER.
BERM TO PROVIDE TREE PLANTING DEPTH ABOVE GROUND WATER.
POSSIBLE CLAY OR GUNITE LAYER, JUST BELOW BOTTOM SURFACE, TO PROVIDE SALT WATER BARRIER.
SLOPED CLAY OR GRAVEL SEAM TO BREAK CAPILLARY ACTION, ABOVE GROUND WATER.

FIGURE 2B: LOW VELOCITY, HARD EDGE BARRIER / TREE PLANTING / DRAINAGE OPTIONS

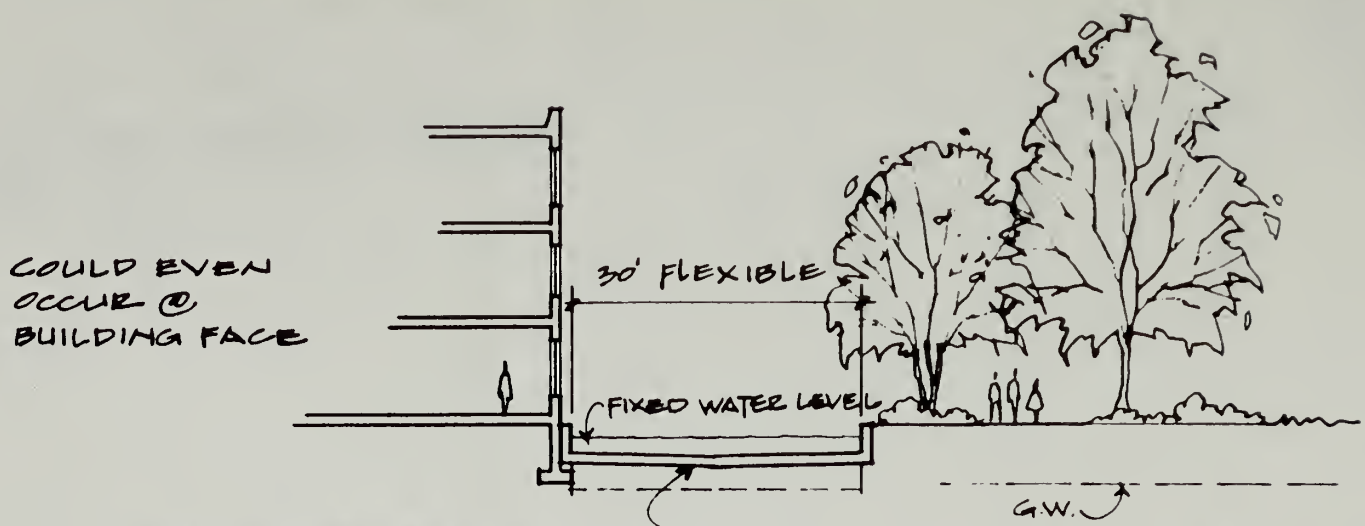
COULD EVEN OCCUR @ BUILDING FACE
30' FLEXIBLE
FIXED WATER LEVEL
G.W.
CONTINUOUS, SHALLOW FULL CONCRETE CONTAINMENT.
"MAXIMUM FLEXIBILITY"
TREES MAY BE PLANTED ANYWHERE BECAUSE OF POSITIVE SEPARATION BETWEEN SALT WATER & SURROUNDING AREAS. — SALT WATER STAYS IN, NUTRIENTS STAY OUT.

FIGURE 2C: HIGH VELOCITY, HARD EDGE — FULL CONTAINMENT

FIGURE 3: SOFT EDGE TREATMENTS

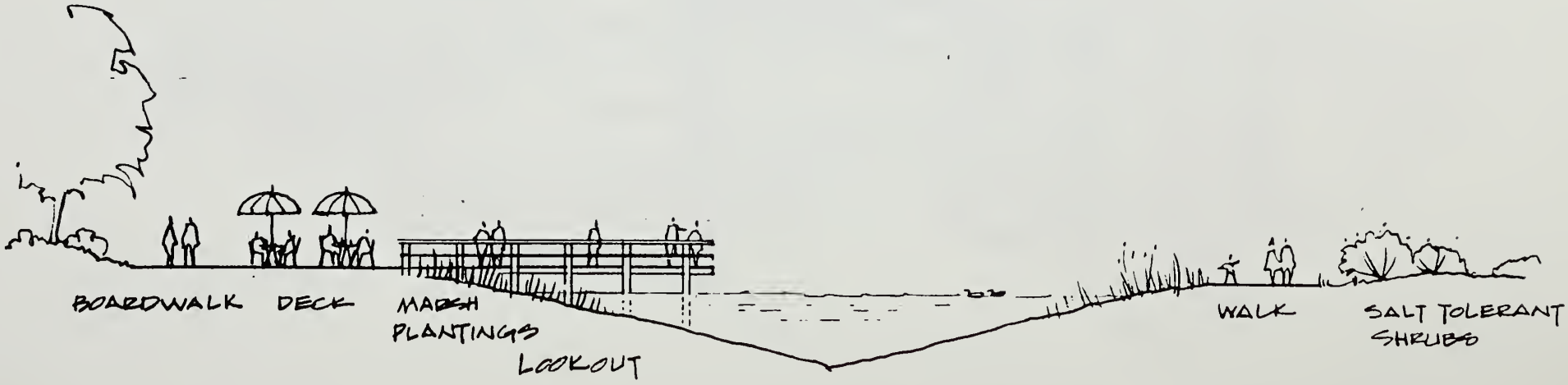

FIGURE 4: SOFT EDGE TREATMENTS

FIGURE 5: HARD EDGE TREATMENTS

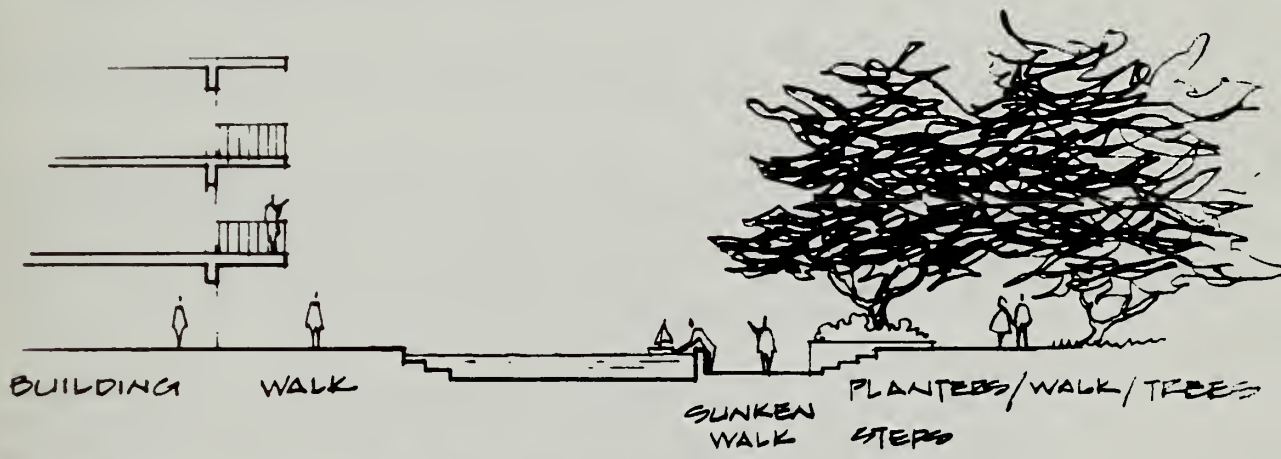

FIGURE 6: HARD EDGE TREATMENTS

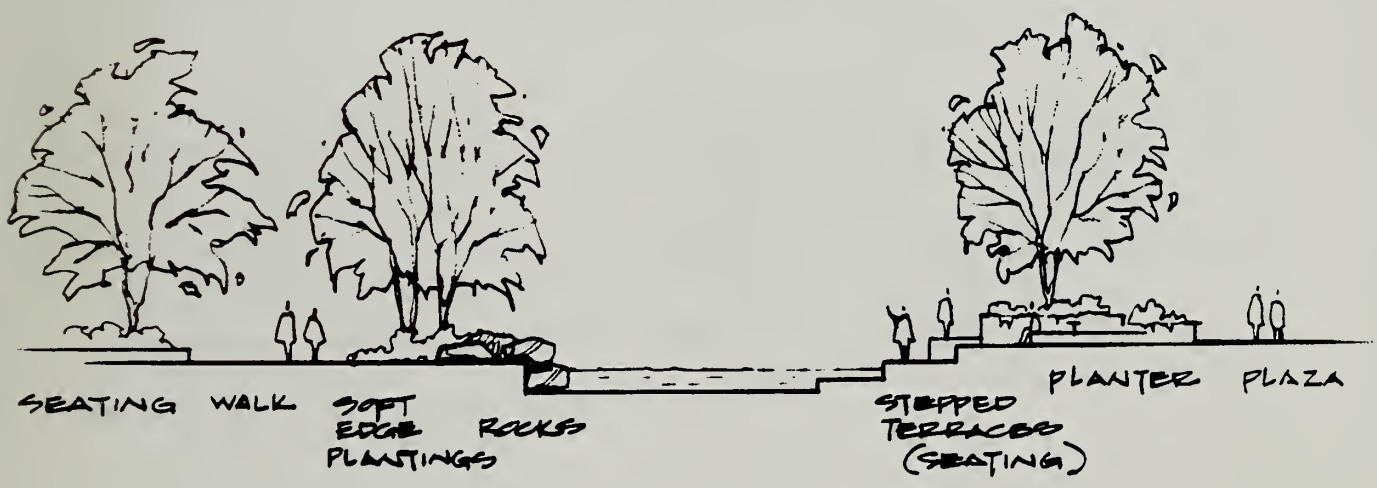

FIGURE 7: HARD EDGE TREATMENTS

SUMMARY

The following is a brief listing of the main conclusions, statements and recommendations drawn from this report:

1. Sewage outflows into the upper end of China Basin Channel constitute a significant potential problem to the planned Mission Bay community.

2. Modification to the existing China Basin Channel geometry, to maximize tidal flushing, is a worthwhile consideration in any event.

3. Addition of a new loop channel, bringing relatively clean Bay water from the south of Pier 54 area to the upper end of China Basin Channel, would greatly improve the Channel's circulation while providing a valuable visual and recreational amenity to the Mission Bay community.

4. A tidal loop channel system does not appear feasible for many reasons compared to a fixed level system.

5. A soft edge, fixed level loop channel system, while possible, appears to be too space consuming for proposed Mission Bay plans. It may have application for somes areas within the plans and could perhaps provide a degree of variety to the overall design. On the otherhand, the soft edge "appearance" within a basic hard edge system has clear application.

6. Fixed level, hard edge systems tend to be more appropriate to the project in terms of utilizing minimal space while offering more flexibility in aesthetic design and overall amenity value to the Mission Bay project.

7. Two fixed level, hard edge options should be considered, (1) Low Velocity, Continuous Flow and (2) High Velocity, Continuous Flow.

8. For a wide variety of reasons, the high velocity option appears to be best hydrologically, structurally and geotechnically while offering the greatest potential for design flexibility and richness in amenity value. It is the least space consuming and has cost advantages over the long term. Its initial construction cost may be somewhat higher, however, further investigations and design refinement are needed before this can be determined.

* * *

WETLANDS RESEARCH ASSOCIATES, INC.

IV. SOURCES AND CAUSES OF ODOR PROBLEMS IN THE SAN FRANCISCO BAY AREA with special concern to the potential for odor problems at the Mission Bay Open Space Element: Wetland creation

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Working document #5

Prepared for:

Philip Williams and Associates
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San Francisco, CA 94111

Introduction

There have been persistent questions concerning the potential for odor problems to develop from mudflats created as part of the wildlife habitat portion of the Open Space Element in the Mission Bay Plan. The primary odor is the familiar "rotten egg" smell associated with anaerobic processes such as those which occur in sewage treatment plant digesters or garbage dumps. The gas responsible for the odor is hydrogen sulfide, a by-product of bacterial degradation of organic matter in the absence of oxygen. In the aquatic environment, hydrogen sulfide is produced in sediments or the water column when oxygen levels are depleted.

The purpose of this report is to discuss the causes of hydrogen sulfide production at nuisance levels and to determine the potential for gas production at the Mission Bay site.

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Causes of hydrogen sulfide production

Hydrogen sulfide is commonly produced in marine and estuarine environments. It is also a by-product of car exhausts, garbage degradation, and sewage treatment processes. It is frequently associated with methane production, however, methane is an odorless gas. Although hydrogen sulfide is a common gas in our atmosphere, it rarely reaches high enough levels to be detectable by human senses. In areas where hydrogen sulfide may be a problem (such as adjacent to a sewage treatment plant) it can be monitored by lead paper strips which turn a specific color upon contact with the gas. The lead paper can sense hydrogen sulfide at much lower levels than detected by the human nose.

Hydrogen sulfide is produced by sulfate-reducing bacteria. These bacteria grow in the absence of oxygen and are called anaerobic bacteria. Rather than using oxygen as an electron acceptor during the process of organic matter degradation, anaerobic sulfate-reducers use sulfate, a common element of seawater. Instead of converting oxygen to carbon dioxide as in aerobic bacteria, sulfate-reducers convert sulfate to sulfide. The bacteria (their scientific name is Desulfovibrio) are common members of the marine environment, but are most frequently found in the bottom sediments.

Oxygen dissolves slowly in water and its concentration is lower in water than in air. It diffuses slowly into sediments and bacterial degradation frequently consumes oxygen faster than it can diffuse into sediments. As a result, beneath the upper few inches of sediment, oxygen is absent. When one disturbs the sediments with a shovel, the lower layers appear black compared to the lighter brown color of the oxygenated region on the surface. This black layer gives off the characteristic odor of hydrogen sulfide. However, the biological production of hydrogen sulfide is relatively slow within marine sediments, and the amount of gas produced is quickly diluted within the water column and eventually the atmosphere.

Nevertheless, odor problems can develop in areas where the activity of sulfate-reducers is accelerated such that hydrogen sulfide is rapidly produced in high quantities. The conditions which can increase odor production include: higher temperatures, greater concentration of organic matter, and reduced circulation which limits diffusion and dilution of hydrogen sulfide. Thus, the most probable occurrence of odor problems is during the summer in areas of limited circulation and high accumulation of organic matter such as sewage or algae. Before the advent of modern sewage treatment practices, raw sewage provided the primary organic source for bacterial degradation in the Bay which resulted in high levels of hydrogen sulfide production at discharge points. In more recent years, odor problems have been primarily associated with large accumulations of drift algae or seaweeds.

Odor problems have frequently been associated with Lake Merritt, a controlled tidal lake in Oakland. As early as 1898, Lake Merritt was branded as a cesspool with thick scum covering the surface. By the mid-1930's, frequent and massive fish kills occurred in the Lake. The source of the problem was the discharge of raw sewage into the Lake. However, once the sewage discharges were removed, excessive growths of algae and odor problems persisted. Over the years, the Lake had become shallower as a result of siltation and large areas became infested with widgeon grass (Ruppia

maritima) and two species of filamentous algae (Enteromorpha and Cladophora). In addition, the construction of the tide gate at the Oakland Estuary retained water in the basin and reduced circulation. The Lake Merritt Restoration Project, completed in 1984, was based on methods to eliminate conditions which encouraged aquatic plant growth. The project involved dredging shallow bottom areas, riprapping the shoreline to eliminate rooting areas, and some annual harvesting of aquatic weeds. It is anticipated that the reduction of aquatic plant biomass will eliminate summer odor problems.

Another area of frequent odor problems has been along the Alameda shoreline. In 1950, "obnoxious odors" were frequently reported coming from areas where seaweeds had accumulated. Dr. Paul Silva of UC Berkeley identified the alga as Ulva and added that pollution in the bay was the primary causative agent. The problem abated for awhile, possibly due to chlorination of waste water which is toxic to algae. When dechlorination of waste water was required during the 1970's, coincidentally, the algal problem regained its earlier public attention. Violations of hydrogen sulfide air pollution standards were recorded in September 1973 and an excessive level (96 ppb for 3 min) was recorded in July, 1974. Seaweeds which grow in south San Francisco Bay were identified as the major components of the accumulating material on the beaches. The primary sources of the odor were stagnant ponds along the shore where the algae accumulated due to onshore drift and wave action. The grading of the ponds, the construction of a fence to control the drift accumulation, and the removal of the accumulated algae on the beach eliminated the odor problem.

Other areas throughout the bay have experienced localized algal blooms, particularly within enclosed or semi-enclosed lagoon system in residential areas and in the salt evaporation ponds operated by Leslie Salt Company. Only a few of the nuisance problems have been investigated prior to their occurrence, the usual causes are excess nutrients, reduced flushing in the area of the bloom, and periodic low water levels which allow sufficient light to reach the bottom. Most remedies to odor problems involve treating the water with algicides or mechanical removal of algal material.

The important point to gain from the above discussion is that mudflats themselves are usually not the culprit in the occurrence of nuisance levels of hydrogen sulfide production. Many communities around the bay are bordered by extensive mudflats and few complaints are registered. In most all cases where nuisance levels of hydrogen sulfide occur, the primary cause is the accumulation of aquatic plant material near or on the shorefront.

Implications for the design of the Mission Bay wildlife habitat

Several questions have arisen during the design phase of the Mission Bay project which will be addressed here:

- How will the sewage discharges affect the production of hydrogen sulfide?
- Will hydrogen sulfide be produced in conjunction with mudflats?

- What design elements must be considered to reduce the production of hydrogen sulfide?

--- The discharge of raw sewage occurs in winter months associated with heavy rainfall. Under most conditions, the sewage is flushed by tidal action out of the China Basin channel within a few days. Solid material and other organics may settle out in the upper end of the channel. This material can add to the organic loading of the benthic sediments. However, because the loading occurs in the cool winter months, biological activity is slow and odor problems are minimal. It is possible that under heavy organic loading during the winter that summer odor problems could develop. However, the tidal flushing of the China Basin channel reduces stagnation. As long as the channel water itself is highly oxygenated, hydrogen sulfide production is kept low during the summer. Under present conditions, no odor problems have been reported by the local residents during the summer months.

--- The mudflats will produce low levels of hydrogen sulfide. However, one would have to be walking in the mud (and therefore disturbing the anaerobic bottom layers) to notice the presence of hydrogen sulfide gas. Boat owners whose boats sat over mud on low tides might also detect some odor. The primary concern in regions with mudflats is the production and accumulation of algae on the shore during summer months. Algae will grow over mudflats during spring and summer months when day time low tides are most frequent and therefore exposing the mudflats to a greater amount of light. While growing, the algae do not produce odor problems, however, if they accumulated on the shore and died, the bacterial decomposition could result in odor problems. The other aquatic weed often associated with odor production during decay is widgeon grass (Ruppia maritima). However, it only occurs in basins with lowered salinities. It is unlikely to occur in the China Basin area unless specific management methods are adopted to encourage fresh or brackish marshes.

--- Design considerations which would limit the occurrence of odor problems at the Mission Bay site are those which primarily reduce algal plant production. Recommendations include:

1. Reduce the loading by solids during winter storm runoff periods.

2. Maintain full tidal circulation in the China Basin channel.

3. Dredge channels to depths below MLLW to reduce light levels near the bottom to reduce growth by aquatic plants.

4. Maintain salinities above 10 to 20 ppt to eliminate growth by widgeon grass (Ruppia maritima).

5. Eliminate design features that allow accumulation of aquatic plant material in "dead-end" sloughs or basins.

6. Do not include underwater sills that might restrict flows into basins or channels.

7. Consider prevailing wind patterns in the design of basins to reduce the possibility of accumulation of algae on leeward edges.

8. Reduce nutrient loading from landscaped areas draining into mudflat areas.

V. MISSION BAY CANAL ALTERNATIVES

We are pleased to present our evaluation of four possible canal construction alternatives for Mission Bay. These four alternatives speak of fixed level and tidal canal construction methods. One of the alternatives (hard edge - high level) was used as the basic design concept for the Mission Bay plan prepared by I. M. Pei. The intent of the following is to provide the planning team with other alternatives that may be appropriate in evaluating the on-going land use standards.

FIXED LEVEL CANAL
HARD EDGE

This option envisions the construction of a 60-foot wide, 8-foot deep canal with retaining walls on each side. If this alternative is selected it is our opinion that the result will be a minimum land requirement, minimum excavation, more or less, and the ability to retain a water surface elevation compatible with the adjoining development. In order to implement this plan it will be necessary to construct, along with the canal improvements, a pump station that will deliver clean waters to the canal system and with a weir configuration capability of lowering the water surface in these canals by approximately 2-feet, as necessary to maintain water quality.

FIXED LEVEL CANAL
SOFT EDGE

In order to provide the planning team with a less rigid approach to the canal water amenities a soft edge concept could be considered. This option will require approximately 50% more land than the hard edge alternative discussed above. If this is a viable alternative, the implications of the shallow water along the edge of the channel should be considered in light of its proclivity for plant growth. It will be necessary, with this option, to provide weirs and a pump station to maintain water quality in a similar fashion to the hard edge option discussed in the foregoing paragraph.

TIDAL CANAL
HARD EDGE

In order to allow the ebb and flow of the tide waters within the canal system, a sheet piled 60 feet wide canal system could be constructed. This alternative would permit tidal flows to enter the canal and rise and fall to a height of 6-feet below the existing ground level to a mean low water of 10-feet below existing ground levels. These limitations will vary during the

course of the year to as much as 1-foot below ground level to 13-feet below ground level. In order to accommodate this significant water surface change, one option would be to install sheet piling along both sides of the canal in order to minimize land requirements and to protect the canal edges. Pump stations and weirs would not be required for this option.

TIDAL CANAL
SOFT EDGE

A method to minimize the appearance of the tidal hard edge alternative could be accomplished by eliminating the hard edge treatment and widening these canal options to accommodate the slopes necessary to replace the sheet piling with earth surfaces. The tidal variation with this option will be identical with those discussed in the tidal hard edge considerations. Again, the shallow water edge characteristics of this soft edge treatment may encourage significant plant growth along the border of the canal. Also, at low water exposed banks with approximately 50-feet on each side of the canal will occur. Each of the tidal options is proposed to maintain 3 feet of water depth at mean low water but this, under severe tidal conditions,could lower to a point where the channel would have no tidal flow.

Several items should be considered in the selection of a canal design appropriate for the Mission Bay Plan, as envisioned by the City of San Francisco, these are: phasing, the need to remove and replace the major sewer storage facility along the southerly edge of Mission Creek, excavation costs that could increase substantially if contamination materials are found on site, and the ability to phase construction of the canals as proposed in the final plan. The implication of these concerns are:

Contaminated Material: During the course of canal excavation, it is possible (probable) that some of the excavation material may be contaminated and may require removal of this soil to a class "A" dump site. Recent experience in eliminating this type of material indicates a cost of $200 per cubic yard for delivery to a class "A" dump site. The magnitude of this consideration cannot be determined until actual excavation begins.

Sewer Storage Facilities: If the selected option is tidal, removal of a portion all facility improvements will be required. Major removal and/or replacment costs will be incurred. If the fixed level hard edge option is implemented the sewage storage improvments will probably remain intact with obvious cost savings.

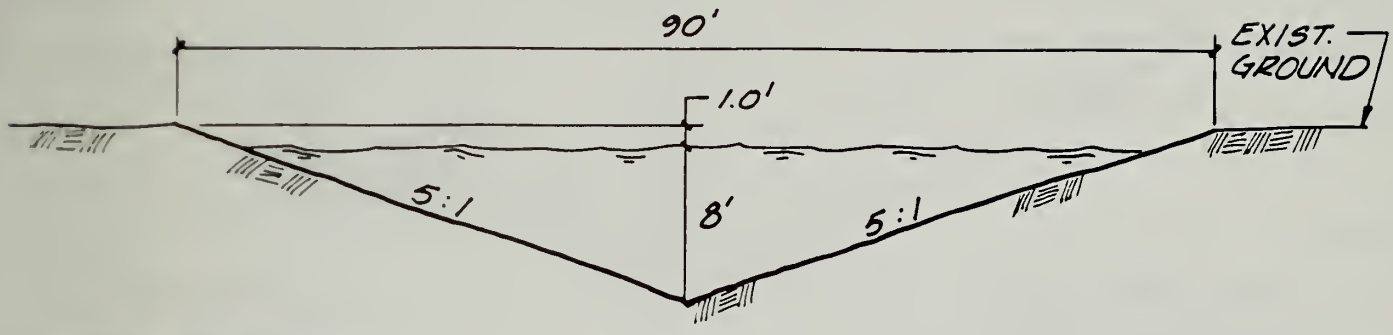
PHASING

Due to the nature of the canal options, it appears that the tidal canals would have to be completed in total to accommodate flows necessary to flush these canals. The fixed level canal would be built in phases as appropriate for the surrounding improvements. In either case, it would be best to complete the canals either tidal or fixed in total, during a single construction period in order to minimize inconvenience, noise, and odor to future residents of Mission Bay.

Even though there are many options open to the planning team, we trust that the four options above will assist all of you in making the proper selection of the canal improvements. If other alternatives become obvious during the planning effort, we would be pleased to provide our overview of these options.

FIXED LEVEL CANAL OPTIONS

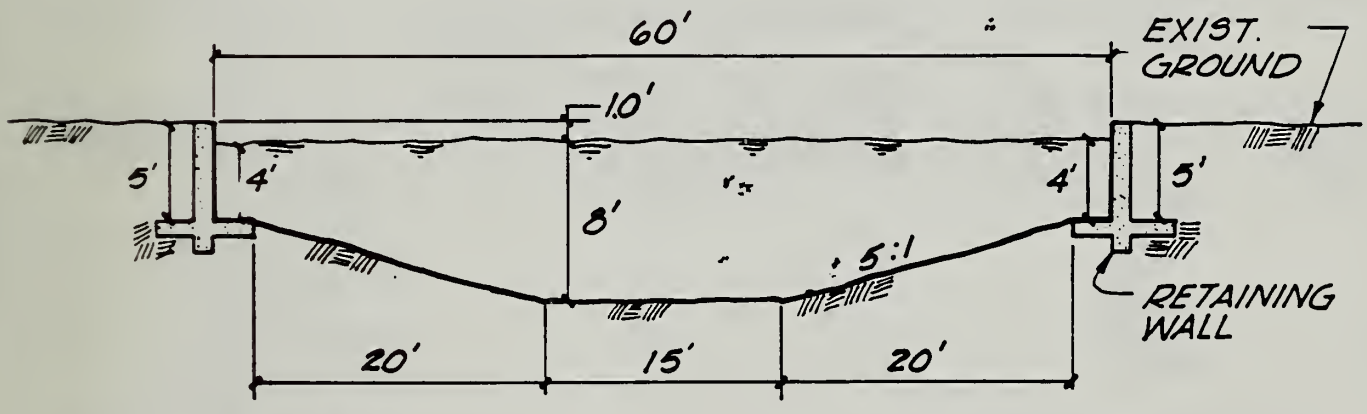
SOFT EDGE



MAJOR QUANTITIES

Excavation: 15 CY/LF
Pump Station
Land: 90 SF/LF

HARD EDGE



MAJOR QUANTITIES

Excavation: 18 CY/LF
Pump Station
Retaining Walls
Land: 65 SF/LF

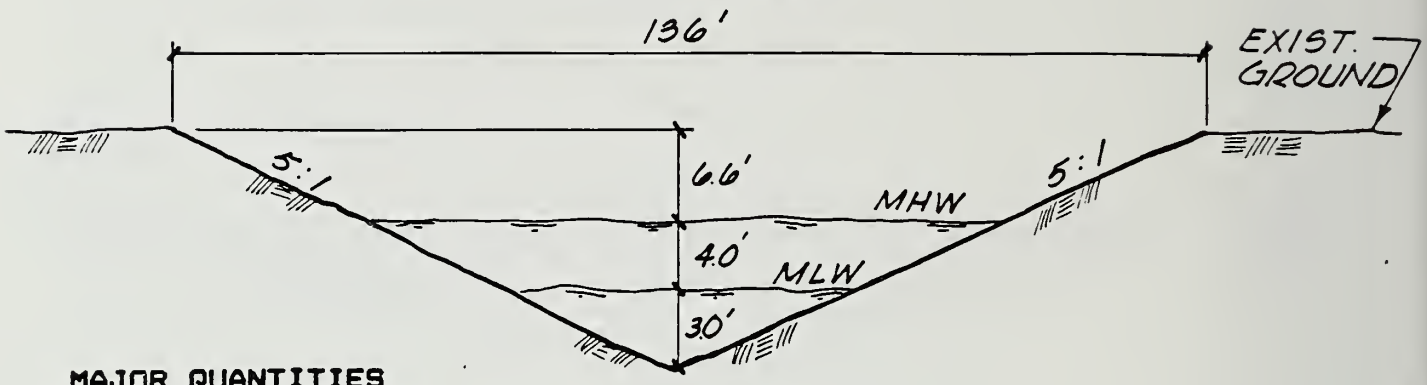
MISSION BAY CANAL STUDY

SHEET 4 OF 7

1936

TIDAL VARIABLE CANAL OPTIONS

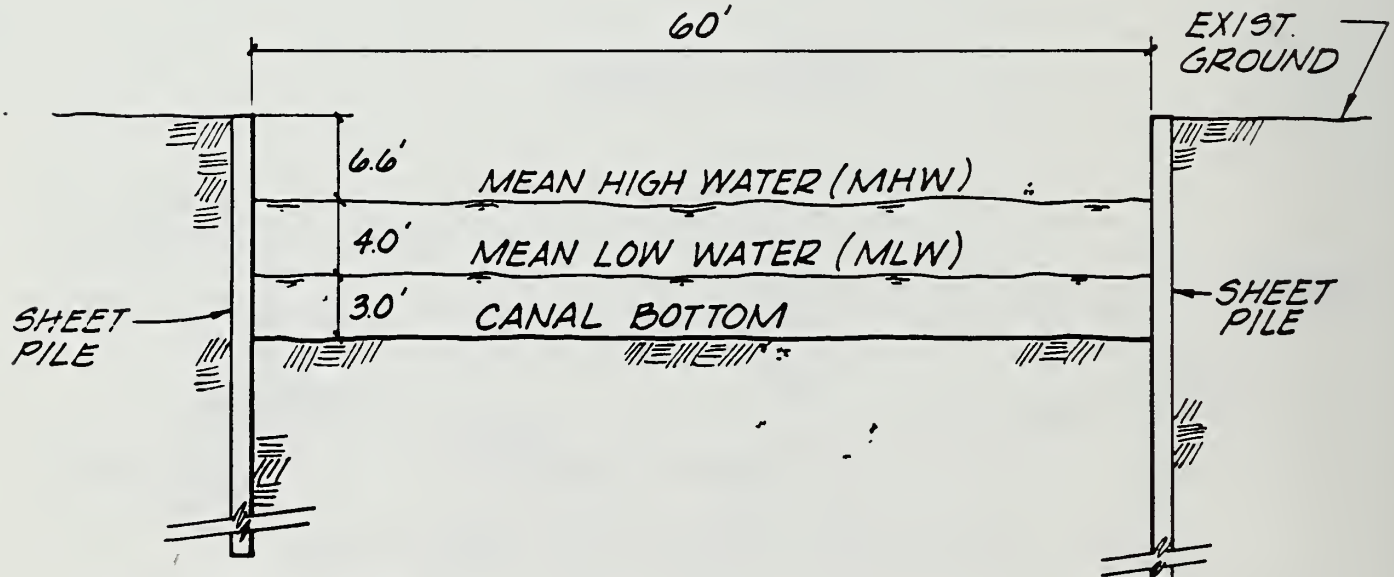
SOFT EDGE



MAJOR QUANTITIES

Excavation: 69 CY/LF
Land: 136 SF/LF

HARD EDGE



MAJOR QUANTITIES

Excavation: 31 CY/LF
Sheet Piling
Land: 60 SF/LF

MISSION BAY CANAL STUDY

SHEET 5 OF 7

1936

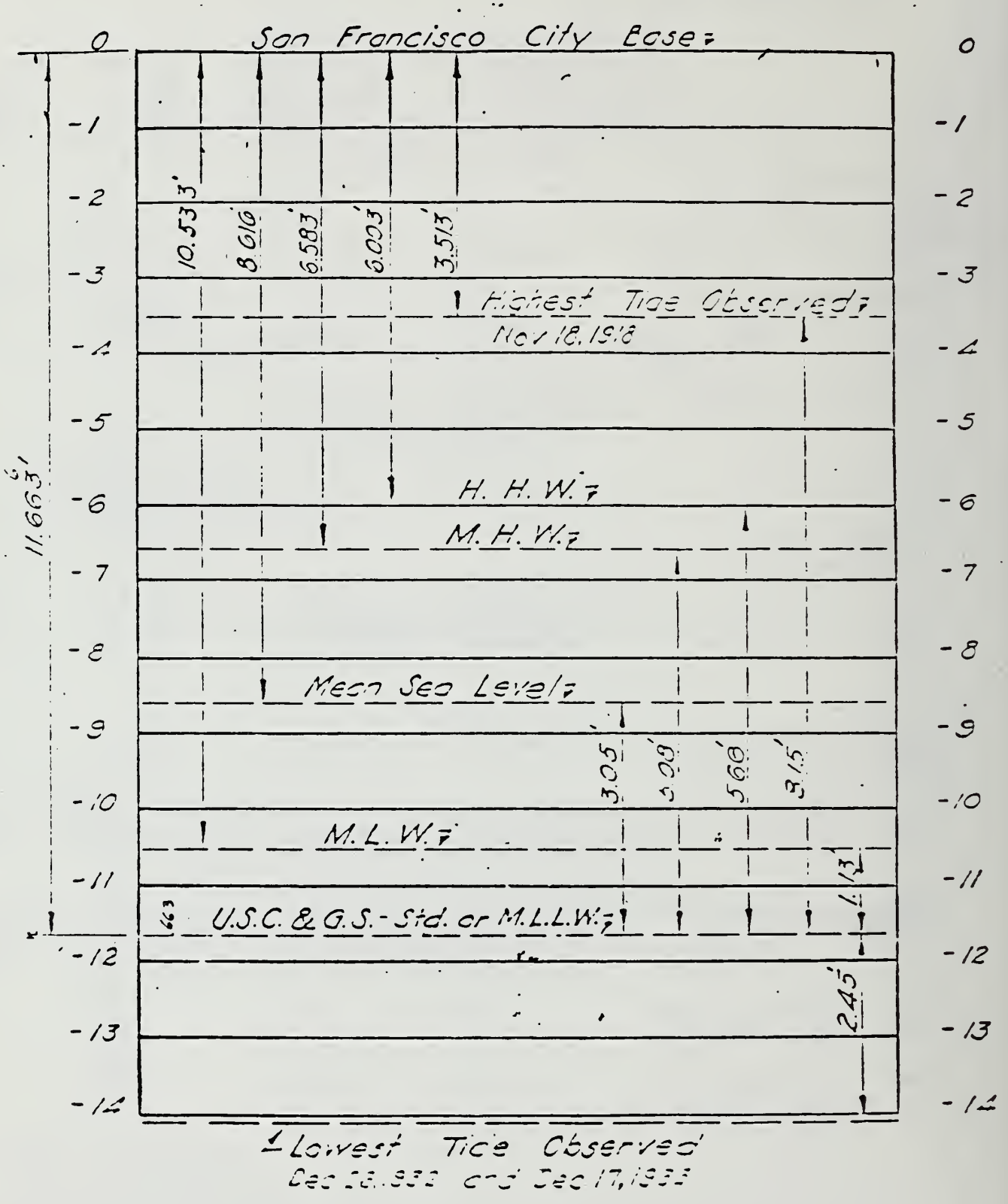
CANAL COMPARISON CHART
Mission Bay
Santa Fe Pacific Realty Corp

	TIDAL		FIXED LEVEL	
	Hard Edge	Soft Edge	Hard Edge	Soft Edge
1. EXCAVATION				
CY per LF	31	69	18	15
Cost at $11/CY/LF	$341.00	$759.00	$198.00	$165.00
2. RETAINING WALLS				
Cost per LF	$0.00	$0.00	$425.00	$0.00
3. MISSION CREEK SEWAGE TUNNEL ALLOWANCE				
Cost per LF	$365.00	$365.00	$0.00	$0.00
4. SHEET PILES				
Cost per LF	$900.00	$0.00	$0.00	$0.00
5. PUMP STATION ALLOWANCE				
Cost per LF	$0.00	$0.00	$300.00	$300.00
Total Construction Cost Per LF	$1,606.00	$1,124.00	$923.00	$465.00
Contingencies, Fees, etc. (at 20.5%)	$329.00	$230.00	$189.00	$95.00
TOTAL COST PER LF OF CANAL	$1,935.00	$1,354.00	$1,112.00	$560.00
TOTAL COST FOR 4600 LF OF CANAL INSTALLED	$8,901,000.00	$6,228,000.00	$5,115,000.00	$2,576,000.00
Land (SF) Required per LF of Canal Installed	60	136	65	90
Land (Acres) Required for 4600 LF of Canal Installed	6.3	14.4	6.9	9.5

NOTES:

1. Cost of vehicular bridges will increased substantially for soft edge options due to increased canal width.
2. Buildings adjacent to tidal canals will require additional foundation costs.
3. If it is necessary to remove contaminated material excavation costs could increase by a factor of 10.

1936
File: MissnBay.Canals



MISSION BAY

SHEET 7 OF 7 SHEETS

KCA ENGINEERS, INC.

CONSULTING ENGINEERS • SURVEYORS • PLANNERS

318 BRANNAN STREET • SAN FRANCISCO CALIFORNIA 94107 • (415) 543 7111

Tidal Variations
Compared to San Fran. Datum

SCALE: None

DATE: Aug '62

DAMES & MOORE

500 Sansome Street
San Francisco, CA 94111
(415) 433-0700

VI. GEOTECHNICAL AND EARTHQUAKE ENGINEERING CONSIDERATIONS OF FIXED LEVEL AND TIDAL CANALS AT MISSION BAY

1.0 This memorandum discusses the pros and cons of alternative construction modes for salt water canals south of the existing tidal China Basin Channel. The following factors have been considered:

- Slope stability for construction and operating conditions;
- Influence on foundation conditions for adjacent structures; and
- Behavior during strong earthquakes.

2.0 Alternative Construction Modes

Construction Mode	Canal Width	Depth of Excavation (ft) Below Existing Ground Surface (Elev. 0 City Datum)	Water Level in Canal
Fixed Level	Hard edge 60 ft.	6 ft. at edge, 9 ft. at center	(fixed) Elev. -1 City Datum
Fixed Level	Soft edge 90 ft.	0 at edge 9 ft. at center	(fixed) Elev. -1 City Datum
Tidal Canal	Hard edge 60 ft.	13.6 ft. at edge and center	Varies with tides Elev. -6.6 MHW -10.6 MLW
Tidal Canal	Soft edge 130 ft	0 at edge 13.6 ft. at center	Varies with tides Elev. -6.6 MHW -10.6 MLW

The descriptive data for these construction modes are basically those used in the IMPEI Plan and as illustrated by KCA Engineers Inc.

3.0 Soil Conditions

In the area being considered for new canal construction (between the existing China Basin Channel, Owens Street, 16th Street, and San Francisco Bay) the site is reclaimed land underlain by:

- Heterogenous fills of highly variable character and thickness (averaging 18 feet and varying from near 0 to a maximum of 57 feet in borings drilled to date). In general, these fills are less pervious than the predominantly dense sand fills "north" of the channel.

- Weak and compressible bay mud extending to depths of 40 to 130 feet below ground surface.

- Firmer sandy and clayey soils overlying bedrock at depths of 50 to greater than 200 feet below ground surface.

Ground water, as measured in borings at the site in 1983, was at a depth of 3.5 to 9 feet below ground surface with an average depth of 6 feet; assuming a ground surface at Elevation 0, City Datum, this water level is about 2.7 feet above mean sea level.

4.0 Slope Stability Considerations

The condition that controls the slope stability of either the hard or soft edge canals is the depth of excavation into the weak Bay Mud that underlies the site fills. The presence of these fills and soft mud nearer ground surface has a critical influence on slope stability, and would require flatter slopes or stronger walls where these poorer soil conditions exist.

For general conceptual studies, average soil conditions (18 feet of fill over Bay Mud, with a water level at a depth of 6 feet) provide a useful point of reference. For these average soil conditions, the retaining walls and slopes for the Fixed Level Canals would be constructed entirely on fills, with Bay Mud about 10 feet below the bottom of the deepest excavation in the center of the canal, and with the footings for the hard edge retaining wall above the ground water table.

Construction conditions for this case are generally favorable with the character of the fill (any rubble or debris?) being the most significant factor. The 5 Horizontal to 1 Vertical slopes used in the IMPEI design below the wall for the Fixed Canal and for the soft edge slope are quite conservative. (For a similar case, Dames & Moore calculated a minimum factor of safety against slope failure of 2.0 for more adverse soil conditions than "average"; see Canal Edge Stability discussion on page 11 of our December 1, 1982 report.) Even if the canals were to be drainged rapidly, the walls would still be stable.

For the Tidal Level Canals, slope stability considerations whould be more adverse than for the shallower Fixed Level Canals. The 5.6 foot deeper excavation would significantly reduce the factor of safety for the 5:1 slopes assumed in the PEI design. No analyses here have been made for the condition. However, if all of the excavation were in fill, such as for the average soil conditions, the 5:1 slopes for the soft edge canal would probably have calculated factor of safety greater than 1.0: but some slope failures are probable for this condition with a rapid draw down of the water level in the canals during extreme tidal variations. Also for more adverse soil conditions (lesser fill thickness with resulting excavations in Bay Mud) the 5:1 slopes may not be stable. Further, as properly indicated on the KCA sketches for the Fixed Level Hard Edge case, the sheet piles would have to be driven to considerable depth below the

bottom of the canal to prevent slope failures through the soft mud (even for average soil conditions). In addition, it is likely that the sheet pile walls would require anchors (or tiebacks) and a heavy structural section to prevent undesirable deflections of the wall.

5.0 Influence on Foundation Conditions for Adjacent Structures

For planning purposes, it is reasonable to assume that the Tidal Level Canals will not have a significant influence on the ground water levels in the existing filled areas of the site. The Fixed Level Canals, on the other hand, could cause a significant increase in the water levels, in areas within 50 to 100 feet of the canals, by establishing a canal water level within one foot of the ground surface and about 5 feet above the average existing water level. This higher water level in the fills would have the obvious disadvantage of placing some basement excavations below water level with the resultant increase in construction costs. The increase in ground water level has one potential advantage from a settlement standpoint by reducing the effective weight of the fills causing consolidation of the underlying compressible bay mud. However, it seems unlikely that this would be a significant advantage in the overall scheme of things because of the limited area affected and the probability that the effect would be non-uniform in any one building area.

6.0 Behavior During Earthquakes

The shallower Fixed Level Canals are superior to the Tidal Canals from earthquake considerations. As discussed previously in Section 4.0, higher factors of safety result from the shallower excavations involved in the Fixed Level design. An even greater influence on earthquake stability is expected because of the unfavorable stability characteristics of the soft mud. The ground movement toward the canal during strong earthquakes are likely to be much greater for the deeper excavations both in amount and in the distance from the canal. As a means of quantifying the effect at this preliminary stage of the project, it is recommended that the width of the zone of significant ground movements be assumed to be 10 times the depth of the canal for the Fixed Level Design (90 feet for the IMPEI plan). To approximate the adverse effect of increasing depth of canal on earthquake stability, the effected earthquake zone a width of 15 times the depth of canal should be used. (200 feet $\pm$ for a 13.6 foot deep excavation).

7.0 Seismic Liquefaction Considerations

As discussed in the Dames & Moore July 9, 1982 report on page 18, the areas of high potential liquefaction of sandy fills during strong earthquakes are expected to be limited to the zone north of the China Basin Channel where dune sand fills were placed in reclaiming the tidelands. For the new canals

south of the channel, the liquefaction potential is low to high depending upon the character of the fills and the ground water elevations. For current planning purposes it can be reasonably assumed that the canals will not be likely to be adversely affected by liquefaction of fills and that the changes in ground water level associated with the Fixed Level Canal will not significantly increase the liquefaction potential in surrounding areas.

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Consultants in Hydrology

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VII. PRELIMINARY ANALYSIS OF A CIRCULATION DESIGN FOR MISSION BAY PROJECT

Philip B. Williams, Ph.D., P.E.
Jeff Haltiner, Ph.D., P.E.
Claude Carlos White, Jr.

Project #303

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2. Conclusions
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5. Measures to Improve Water Quality
6. Analysis of Circulation
7. Results

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Appendix B. Description of alternative pumped circulation systems

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1. Longitudinal cross-section of Mission Creek
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1. INTRODUCTION

The proposed Mission Bay project design includes extensive development around the Mission Creek channel. This tidal channel is used to discharge overflows from the San Francisco combined sewer system to San Francisco Bay whenever sewer storage capacity is exceeded. With the improvements now being completed, the City estimates that discharges will be reduced to a frequency of about 10 per year.

There is concern that these discharges of mixed stormwater and primary treated sewage are incompatible with the proposed Mission Bay project and that measures should be included in the design to reduce their impact.

This report is a preliminary assessment to indicate the type of design measures that might be required to improve circulation and flushing in the Mission Creek channel.

2. CONCLUSIONS

1. The nature and extent of water quality problems in the Mission Creek channel due to sewage overflows has not yet been quantified or defined.
2. If discharges continue to be made into the channel, circulation can be improved by increasing the tidal prism above 5th St. by widening existing shallow water areas.
3. Circulation can also be improved by constructing a tidally pumped looped channel, discharging into the upper end of Mission Creek channel.

4. Circulation can also be improved by pumping clean Bay water into the upper end of the Mission Creek channel.
5. Pumping rates of the order of 100,000 gpm would greatly reduce any pollution problems.
6. Deepening the Mission Creek channel at the upper end can significantly reduce dispersion of pollutants and extend the time required to accomplish flushing.

2. DEFINITION OF THE PROBLEM

At present the level and type of pollution within the Mission Creek channel has not yet been defined. It appears that discharges of varying amounts and concentrations occur during winter and spring. During periods of high runoff, large discharges can occur that fill the channel before tidal action disperses them. A typical maximum annual discharge event is of the order of 200 to 300 acre-ft.

When large discharges occur, pollutants are likely to be significantly diluted by stormwater. In addition, large discharges occur when water temperatures and solar radiation are low and dissolved oxygen levels are high.

At present it appears that under the requirements for the San Francisco Wastewater Treatment Program, the Regional Water Quality Control Board has set discharge standards for the mouth of Mission Creek where it discharges to San Francisco Bay, but not at the actual discharge point at the upstream end. It is

therefore evident that water quality standards for body contact are regularly exceeded in the channel whenever there is a discharge.

A precise definition of water quality problems in the channel requires an extensive monitoring and sampling program. In the absence of such information there is currently no objective definition of the water quality problem in the Mission Creek channel.

However, from the perspective of the proposed development, impacts on aesthetics and odor are perceived to be significant potential problems, although the average number of days per year in which these would occur may be less than ten. Odor and aesthetic problems can also develop in the summer, unassociated with discharges, if algal blooms occur during high temperature periods, then die and decay, reducing dissolved oxygen levels in the water.

3. EXISTING CIRCULATION PATTERN

At present, under normal conditions, sewage discharges into the upper end of the channel appear to disperse to a level that is not noticeable within a matter of a few days. This is due to both tidal flushing and density-driven circulation.

Figure 1 shows a cross-section of the Mission Creek channel. It can be seen that because the upper end of the channel has silted in, the mean tidal prism -- the volume of water moved in

and out in a mean tidal cycle -- is quite large compared to the total volume. This means that even though this is a dead-end channel, tidal circulation is quite large. Another factor favoring circulation is that the channel discharges into San Francisco Bay at a location where tidal currents are very strong and disperse pollutants rapidly.

Tidally induced circulation is reduced when tidal flushing is weakest, during the four or five days per month of neap tides. Conversely, tidal flushing is most effective during the six or eight days each month of the spring tide period. Table 1 shows the tidal characteristics for Mission Creek.

Density-driven circulation occurs because the inflowing sewage discharge is freshwater and has a lower density than seawater. The freshwater can flow out of the channel on top of the salt water with only partial mixing. This flow stratification creates a counter current in the deeper salt water, inducing a net water movement that can be many times greater than the original discharge rate. This greatly accelerates flushing of the pollutants out of the channel.

The process is illustrated in Figure 2 which shows the salinity and dispersion of a small sewage discharge that occured during a spring tide period in 1979.

The most serious water quality problems develop when the

density stratification is destroyed and the channel becomes completely mixed. This could occur if the discharge was appreciably colder than the salt water, if the salt water had been diluted by floodflows, or if vigorous wave action caused mixing.

4. MEASURES TO IMPROVE WATER QUALITY

There are two strategies to improve water quality in the channel:

- Eliminate sewage discharges;
- Improve circulation to flush out sewage as rapidly as possible.

Eliminating discharges requires either moving the discharge point, or building sufficient storage to contain overflows of the storm drain system.

The subject of this report is how to improve circulation. Three alternative methods are:

a. Modifying the existing channel geometry to maximize tidal flushing.
b. Constructing a new tidal channel linked to the end of the Mission Creek channel to create a net tidal circulation.
c. Providing a pumping system to discharge clean Bay water into the upper end of the channel.

5. ANALYSIS OF CIRCULATION

The analysis of circulation in a tidal stratified channel is

very complex and imperfectly defined. Its analysis requires field data to calibrate dispersion models. For the purpose of this preliminary analysis comparing the effectiveness of different alternative ways of improving circulation, a simple computer model was developed that divided the channel into four segments (see Fig 1). Computations of net dilution were carried out for every half tidal cycle assuming complete mixing within each segment (no stratification) and no longitudinal dispersion. It was also assumed that complete dispersion of a pollutant occurred beyond 3rd St. and that the initial concentration of the conservative pollutant was 100 at the start of each simulation.

6. RESULTS

Table 2 summarizes the results of 13 computer runs. The program calculates the concentration of a conservative pollutant at the end of each ebb and flood tide assuming complete mixing and an initial concentration of 100. The number of complete tidal cycles required to dilute the initial concentration of pollutants in the channel above 6th St to the 10% and 1% level are shown in each scenario.

The only dispersion data presently available is a test on a 50 acre-ft discharge occuring during a spring tide in 1979. As shown in Figure 2, the discharge dispersed to less than 1% concentration in two tidal cycles. This discharge was simulated with the computer model as Run 3. Eight tidal cycles were predicted to reduce the concentration to less than 1%. The difference between the prediction and measured dispersion is

probably largely due to the stratification shown in Fig. 2. Because the model does not include the stratified flow dispersion mechanism, the results should be used only as a means of judging the relative effectiveness of alternatives and not used as predictions of actual concentration levels.

The relative effect of different tides is shown by comnparing Runs 1 and 2. It can be seen that dispersion is about 50% slower during the 3 ft neap tide sequence. A typical plot of dispersion rate is shown in Figure 3. Circulation can be improved by increasing the tidal prism at the end of the channel. Run 4 was carried out assuming the channel upstream of 5th St was doubled in area but maintained at the existing depth. Comparison of Runs 4 and 1 shows a 50% improvement in dispersion rates.

In its present state, the channel has shallowed considerably and will eventually develop into mudflats, impeding outflow from the sewer outfall. To prevent this the channel may have to be dredged. In addition, long-term maintenance dredging of the basin should be conducted. Runs 5 and 6 assumed the channel was dredged to -10 ft. MLLW throughout. This increase in depth impairs circulation, because it retains a higher volume of water at the upper end of the channel where circulation is most restricted.

Runs 7 through 10 show the improvement in circulation if a looped, tidally pumped channel was constructed connecting with

the upper end of the existing channel (Runs 7 and 8) or connecting at 6th St (Runs 8 and 9). This system is described in Appendix A. The analysis assumes a 4000 ft long, 50 ft wide channel that would empty 13.8 acre-ft in a neap tide into Mission Creek on the ebb tide and be filled from its inlet at Mission Rock on the flood tide. Comparison of Runs 7 and 1, and 8 and 6 indicate that dispersion rates would be doubled if discharge from the looped channel occurred at the end of the channel and improved about 50% if discharge occurred at 6th St.

Runs 11 through 13 show the effect of continuous pumping at different flow rates into the end of the channel. Figure 4 shows that to achieve the same improvement in circulation equivalent to about half the dilution time of the existing channel, 20,000 gpm or about 50 cfs will be required.

APPENDIX A

Description of tidally pumped alternative for improved circulation in the Mission Creek channel

The principle behind this alternative is to use tidal energy to pump water into the upper end of Mission Creek during the ebb tide cycle. This is done by constructing a new channel from the vicinity of Mission Rock to the upper end of Mission Creek. Tide gates would be placed on the Mission Rock end to allow inflow during the flood tide only. Another set of tide gates would be placed on the western end to allow discharge during the ebb tide into Mission Creek while preventing sewage discharges from backing into the tidal channel.

The effectiveness of this system increases with the tidal volume that can be released into Mission Creek. The tidal volume or tidal prism is maximized if the length, width and tidal range are maximized. It appears that the feasible length of this channel is approximately 4000 ft. The width may vary depending on what adjacent land uses are selected. A range of width from 30 to 100 ft appears feasible. (In the analysis contained in this report, a width of 50 ft was selected). The tidal range in the new channel would be the full tidal range, the same as in Mission Creek and the Bay.

The hydraulics should be such that the channel is not so constricted as to impede discharge during the ebb cycle. While this has not yet been accurately computed, it appears that for a 50 ft channel, a depth of -8ft NGVD would be satisfactory.

Similarly, culverts under road crossings should not constrict the flow too greatly.

Another consideration in the design is sedimentation of muds carried in during the tidal cycle. Approximately 2 ft should be allowed at the bottom of the channel for sediment accumulation, making the total channel depth approximately -10ft NGVD.

A typical cross-section of the tidal channel is attached. Walls or steeper slopes are hydraulically more efficient in the functioning of this system than shallow natural edges, such as mudflats or marshes.

Maximum tide elevations during storm surges could be controlled by closing the tide gates at the eastern end. However, it would be prudent to design for maximum 100-year storm surge water elevations of approximately 7 ft NGVD (excluding the effect of sea level rise).

The channel could also be used as part of the storm drain and street drainage for the project.

APPENDIX B

Description of artificially pumped circulation system for the Mission Creek channel

There are four alternative approaches to using a pumped system to improve circulation in the Mission Creek channel:

1. Underground Pipeline

With this system, a pump station near Mission Rock would discharge to Mission Creek through a pressurized pipeline. This pipeline would be buried and probably be in the 36-in. to 60-in. diameter range. The pumps would only be turned on when water quality problems in the channel occurred. With this type of operation, the pump capacity would be large, possibly 50,000 to 100,000 gpm, operated only a few times each year. An energy dissipator or diffuser would be required at the discharge point. However, even with 100,000 gpm, additional flow velocities in the Mission Creek channel would be low.

2. Open Channel - low velocity continuous flow

With this alternative, a smaller pump station located in the Mission Rock area would continuously discharge directly into a channel that would flow westwards through the development to discharge at the end of Mission Creek. The channel would be about 30 to 100 ft. wide and deep enough to prevent algae growth on the bottom, (approximately 3 ft.) with an additional 1 ft. to allow for sedimentation. Allowing for about 2 ft. of freeboard, the total channel depth would be approximately 6 ft. With this depth, the channel bottom need not be lined. It would be advisable to have vertical or steep banks to minimize shallow

water areas where algae can grow. In this alternative the water level would be constant. A typical cross-section is shown in Figure B-1.

3. Open channel - low velocity varying flow

A variation of alternative 2 is to release water from the channel only during the ebb tide in Mission Creek. Releasing a given amount of water during the ebb is somewhat more effective in flushing pollutants than releasing the same amount of water continuously, and so the total amount of pumping required would be less than for alternative 2. In this operation, the channel acts as a reservoir being pumped full during the flood tide and discharged during the ebb. The water level would fluctuate about 4 ft., requiring a total depth of about 10 ft. allowing 2 ft. of freeboard. Channel sides could be made vertical to minimize algal growth, or alternatively, gently sloping if a fringe of marsh vegetation was desired.

A typical cross-section is shown in Figure B-2.

4. Open channel - high velocity continuous flow

In this alternative, a shallow, fast-moving stream flowing through the development would discharge at the upper end of Mission Creek supplied by a pumping station near Mission Rock. For a channel flowing approximately 1 ft. deep and 20 ft. wide for a 20,000 gpm pumping rate, the total head loss over the 4000-ft. length would be about 10 ft. This would then probably require two booster pump stations along the length of the

channel, each lifting the water about 3 1/2 ft. if deep excavations are to be avoided.

Typical velocities in the channel would be about 3 ft./second. This would prevent sediment accumulation, but may not be sufficient to prevent algal growth on the channel bottom. Therefore, the channel would have to be lined to allow for cleaning.

A typical cross-section is shown in Figure B-3.

REFERENCES

CH2M Hill. "Report for City and County of San Francisco: Bayside Overflows". June, 1979, San Francisco.

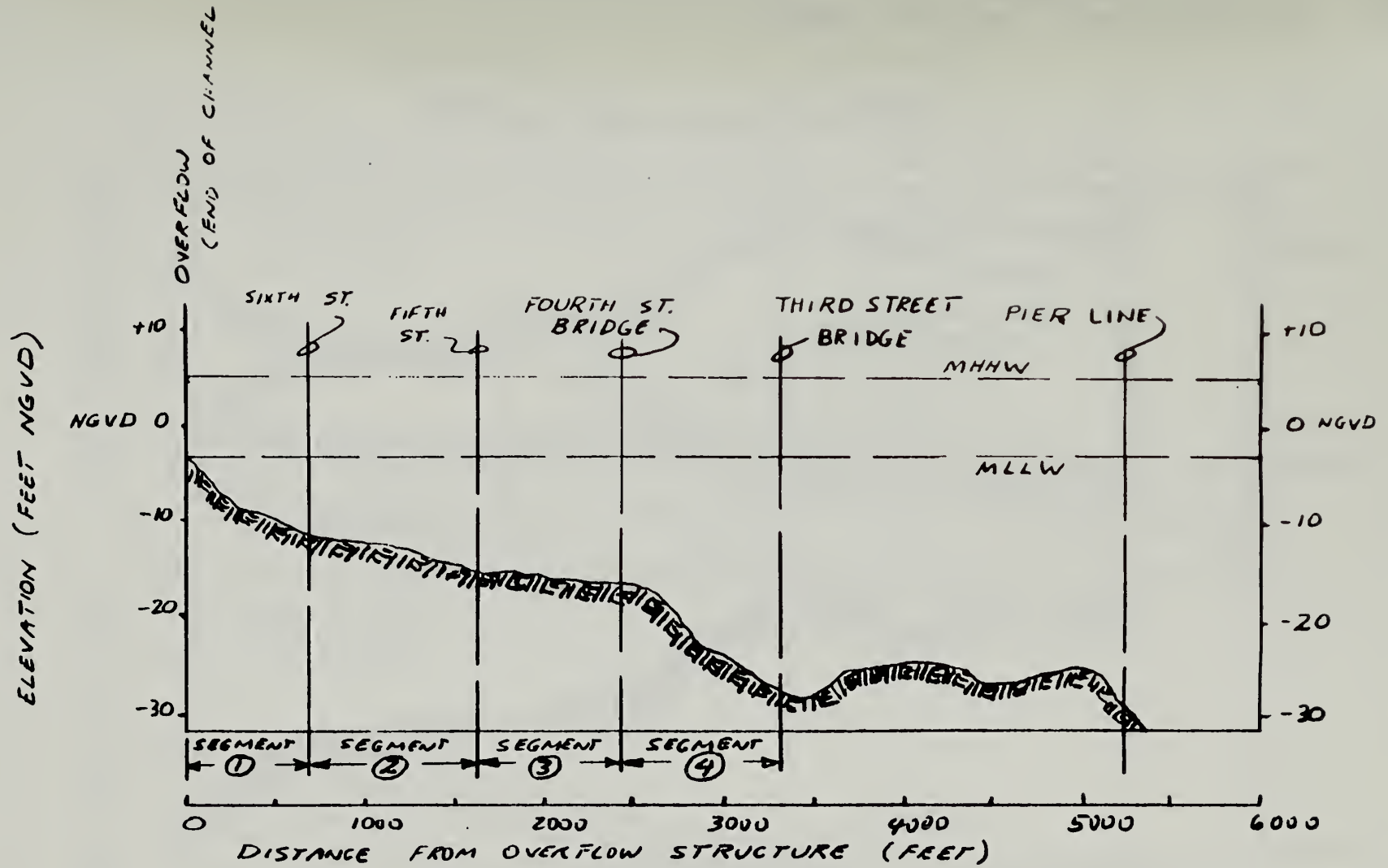
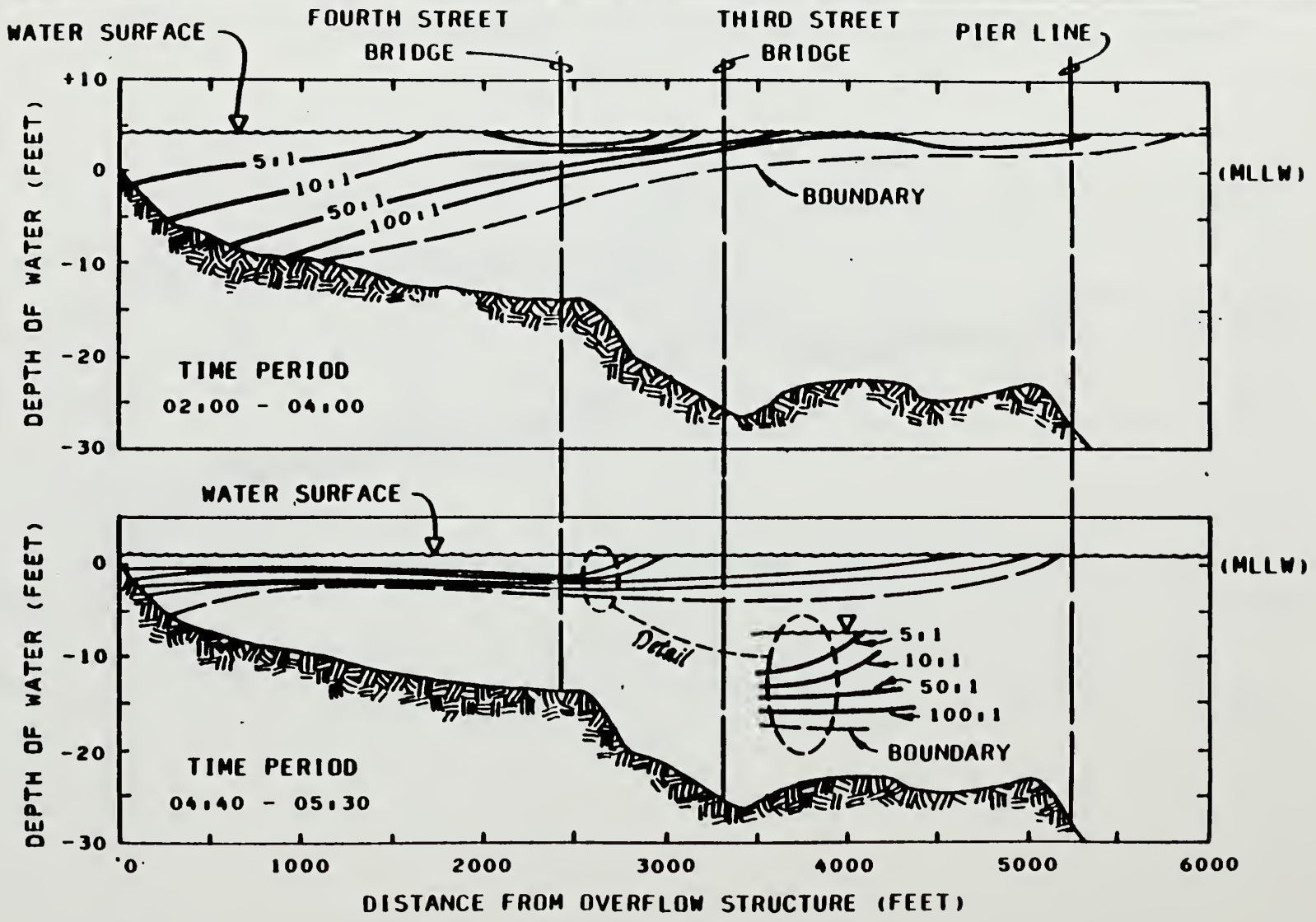


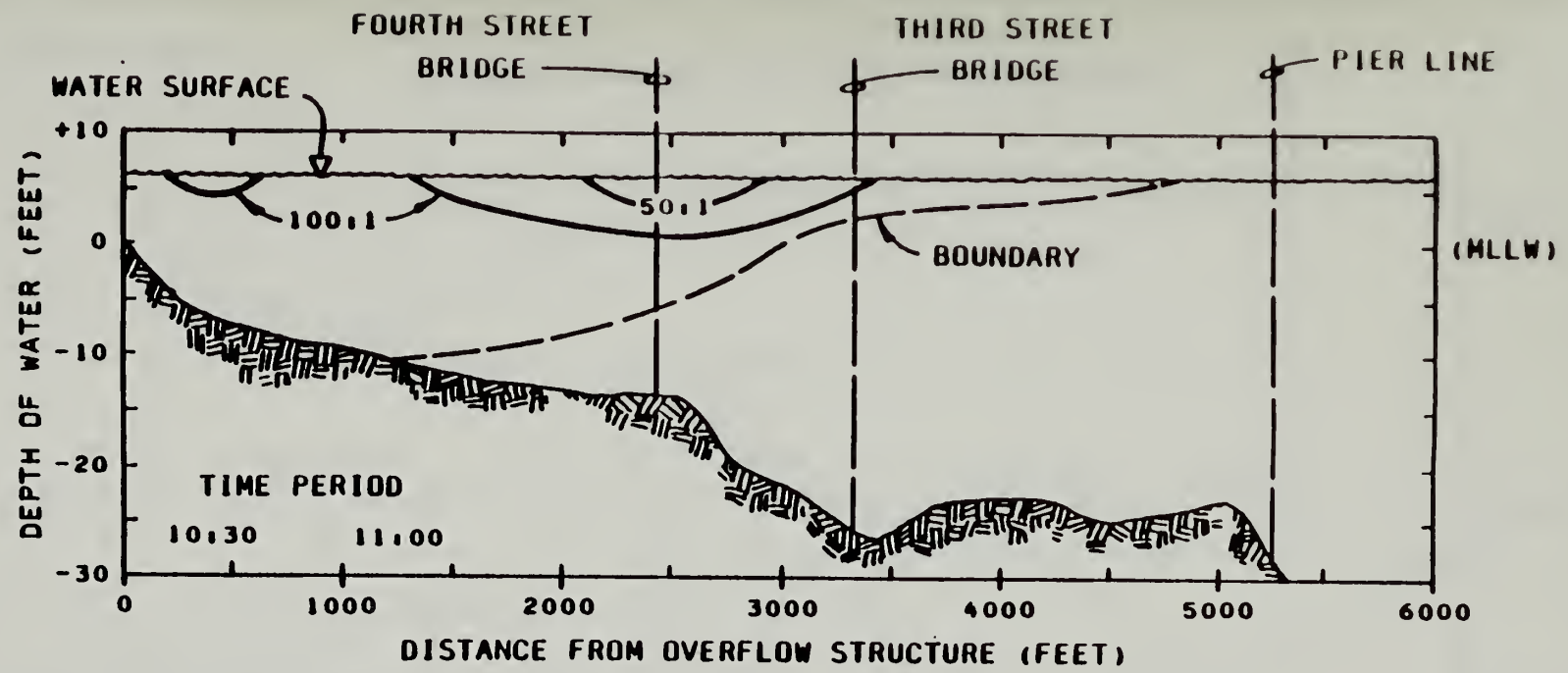
FIG. 1 SECTION ALONG THE LENGTH OF MISSION CREEK



CHANNEL OVERFLOW - DILUTION PROFILES
27 MARCH 1979

FIG. 2a

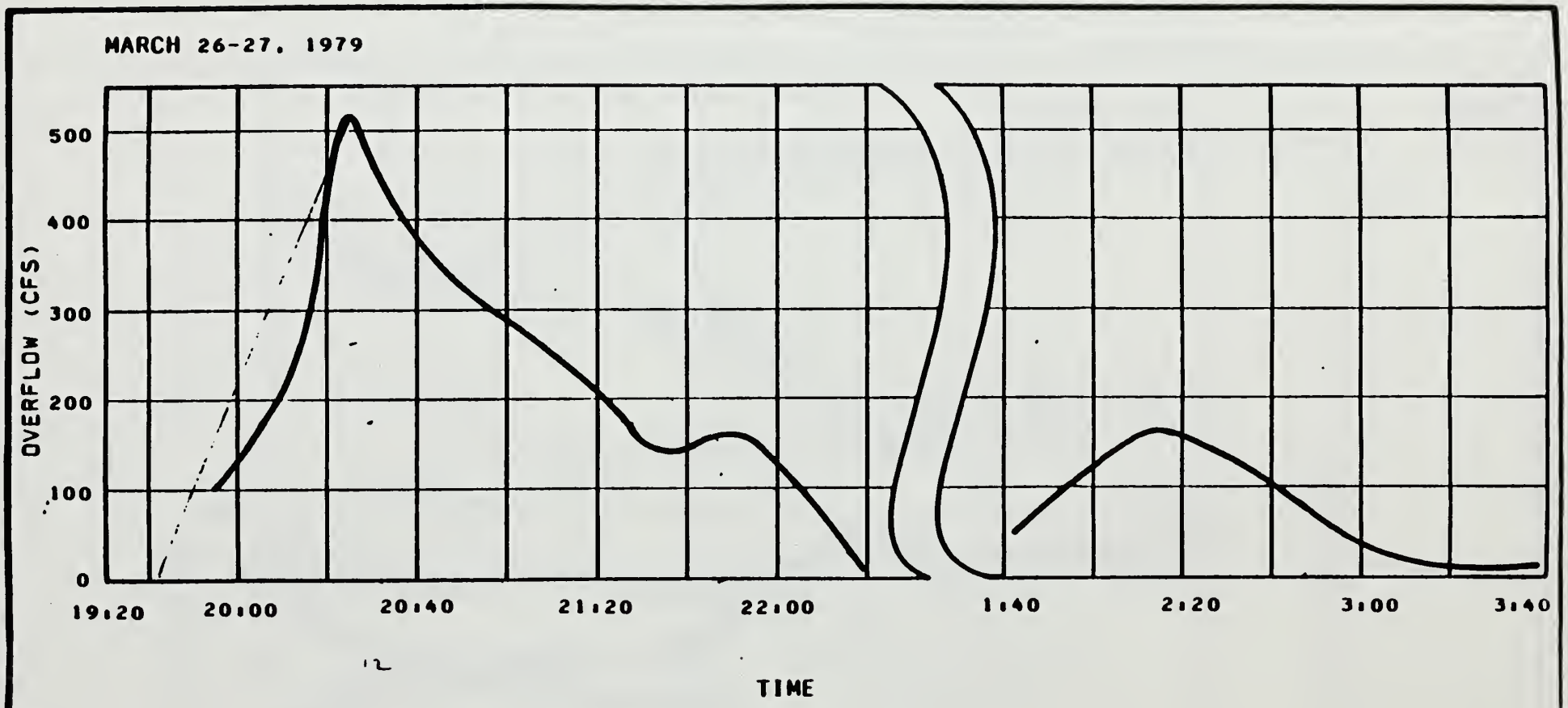
SOURCE: CH2M HILL, 1979



CHANNEL OVERFLOW - DILUTION PROFILES
27 MARCH 1979

FIG. 2b.

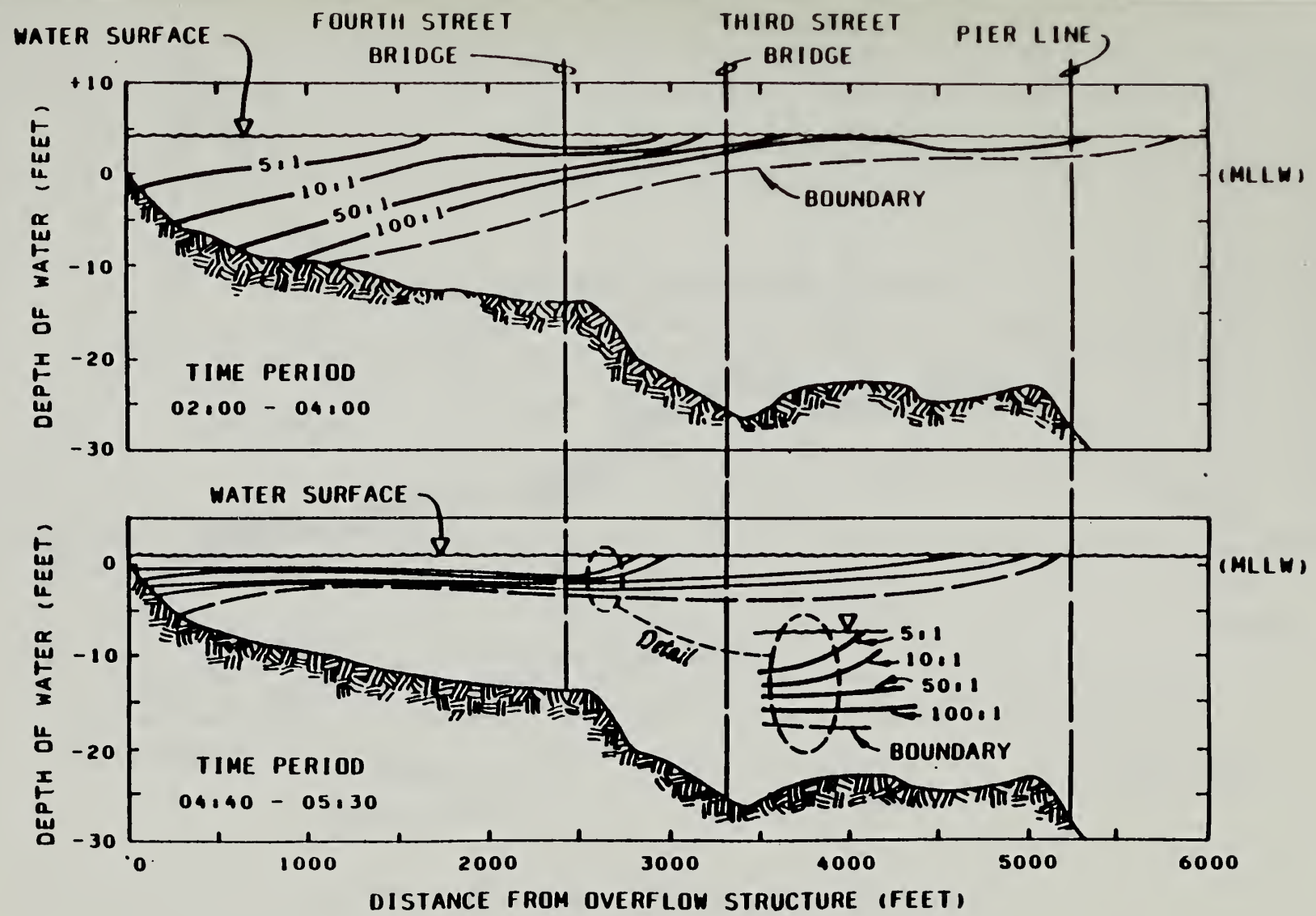
SOURCE: CH2M HILL, 1979



OVERFLOW FROM THE DIVISION SEWER (CHANNEL)

FIG. 2C

SOURCE: CH2M HILL, 1979

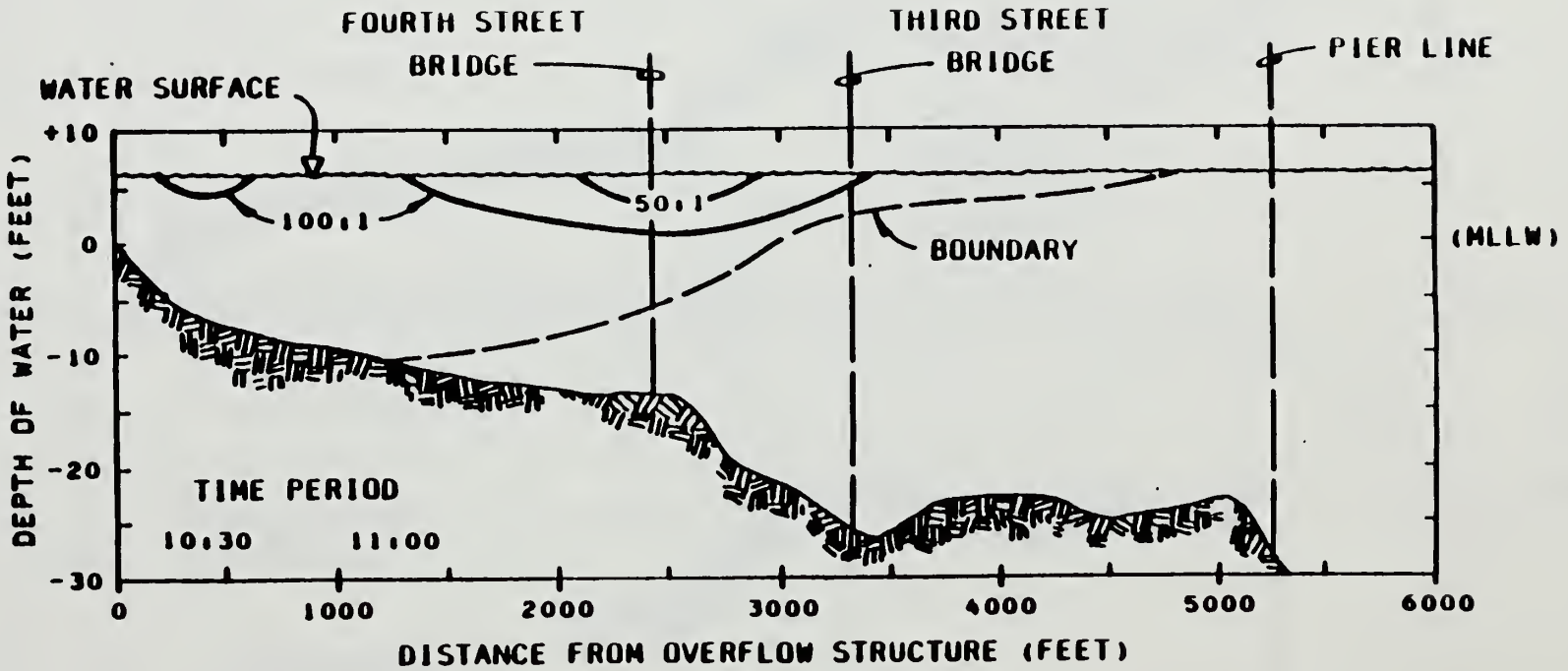


CHANNEL OVERFLOW - DILUTION PROFILES
27 MARCH 1979

CH2M HILL

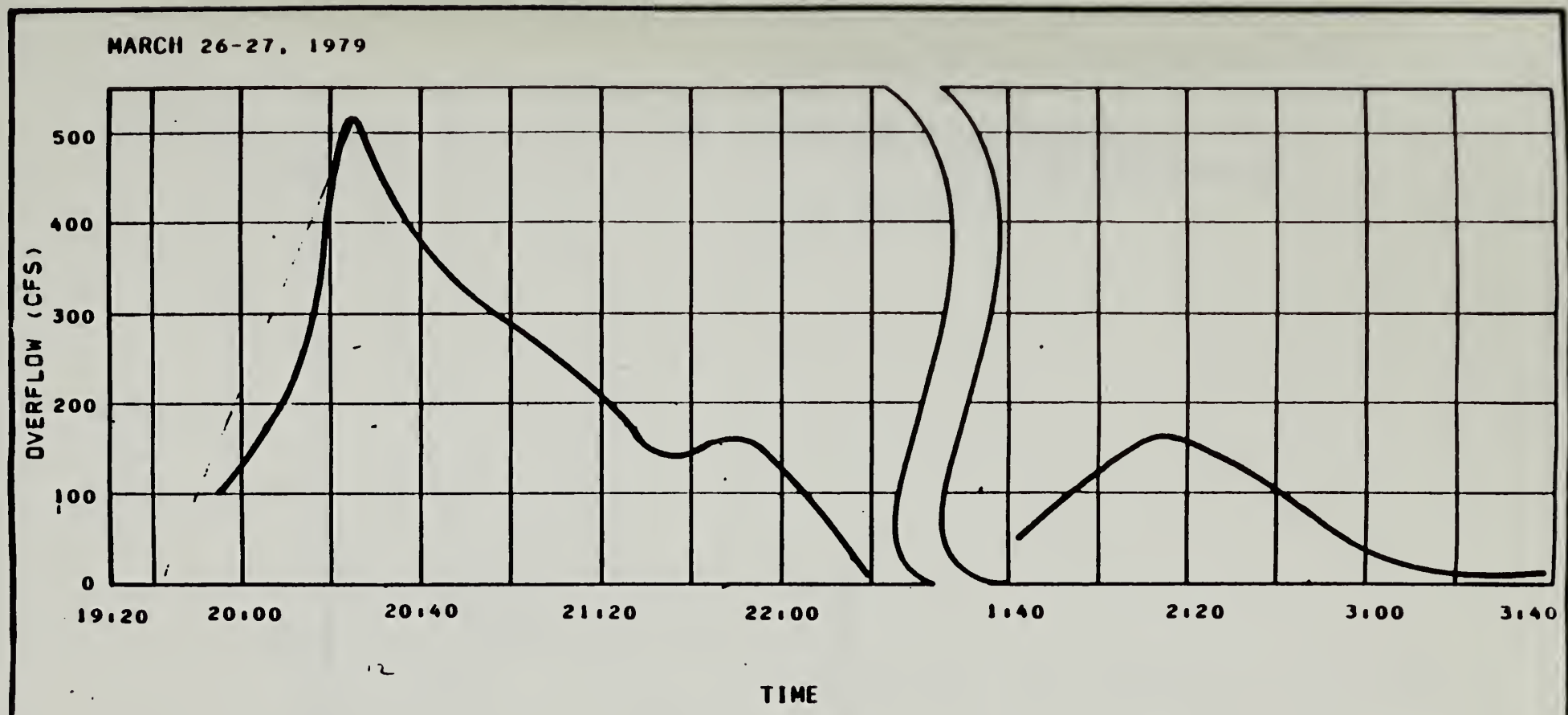
Fig. 2a

Source: CH2M Hill, 1979



CHANNEL OVERFLOW - DILUTION PROFILES
27 MARCH 1979

FIG. 2b



OVERFLOW FROM THE DIVISION SEWER (CHANNEL)

Fig. 2c

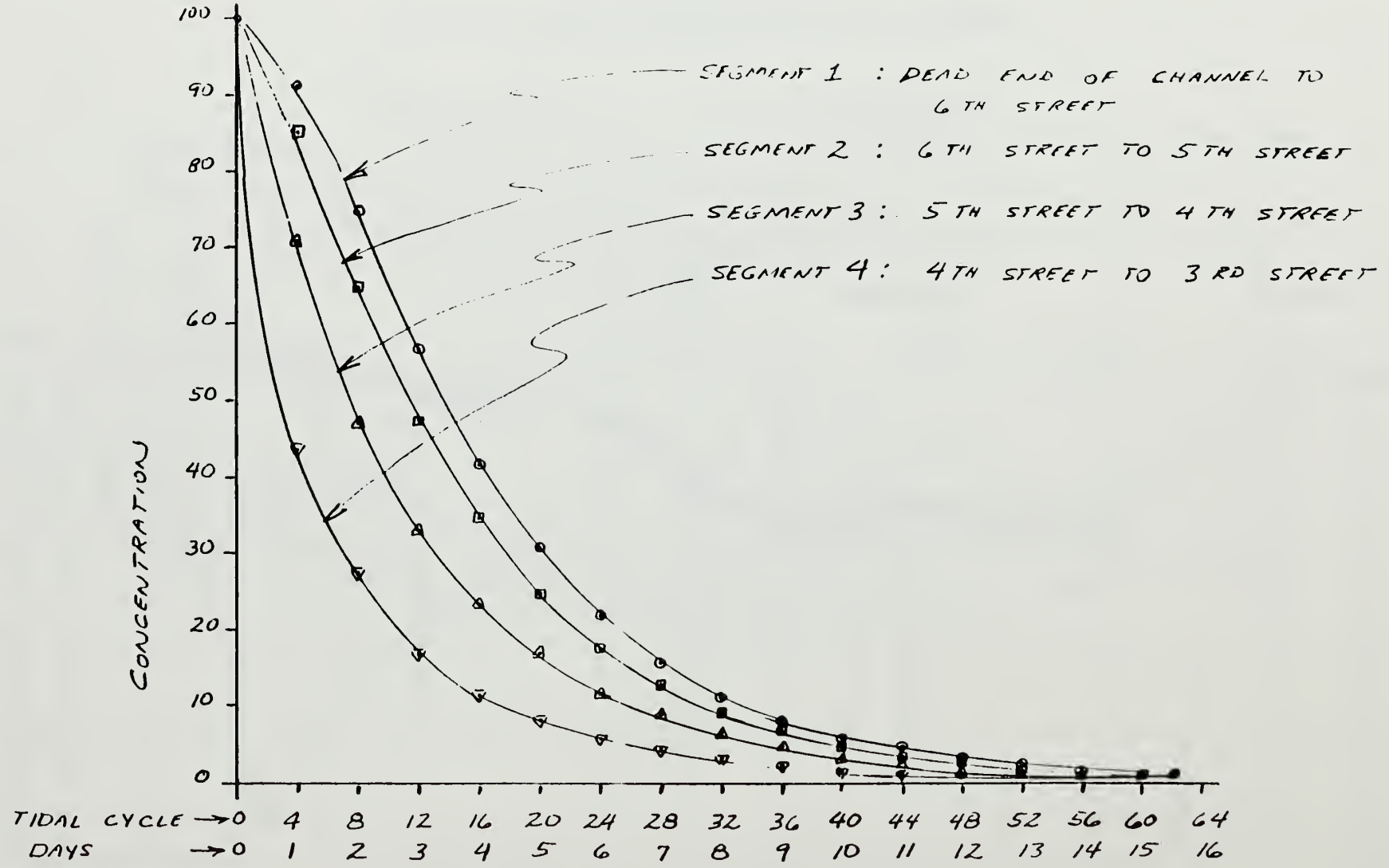
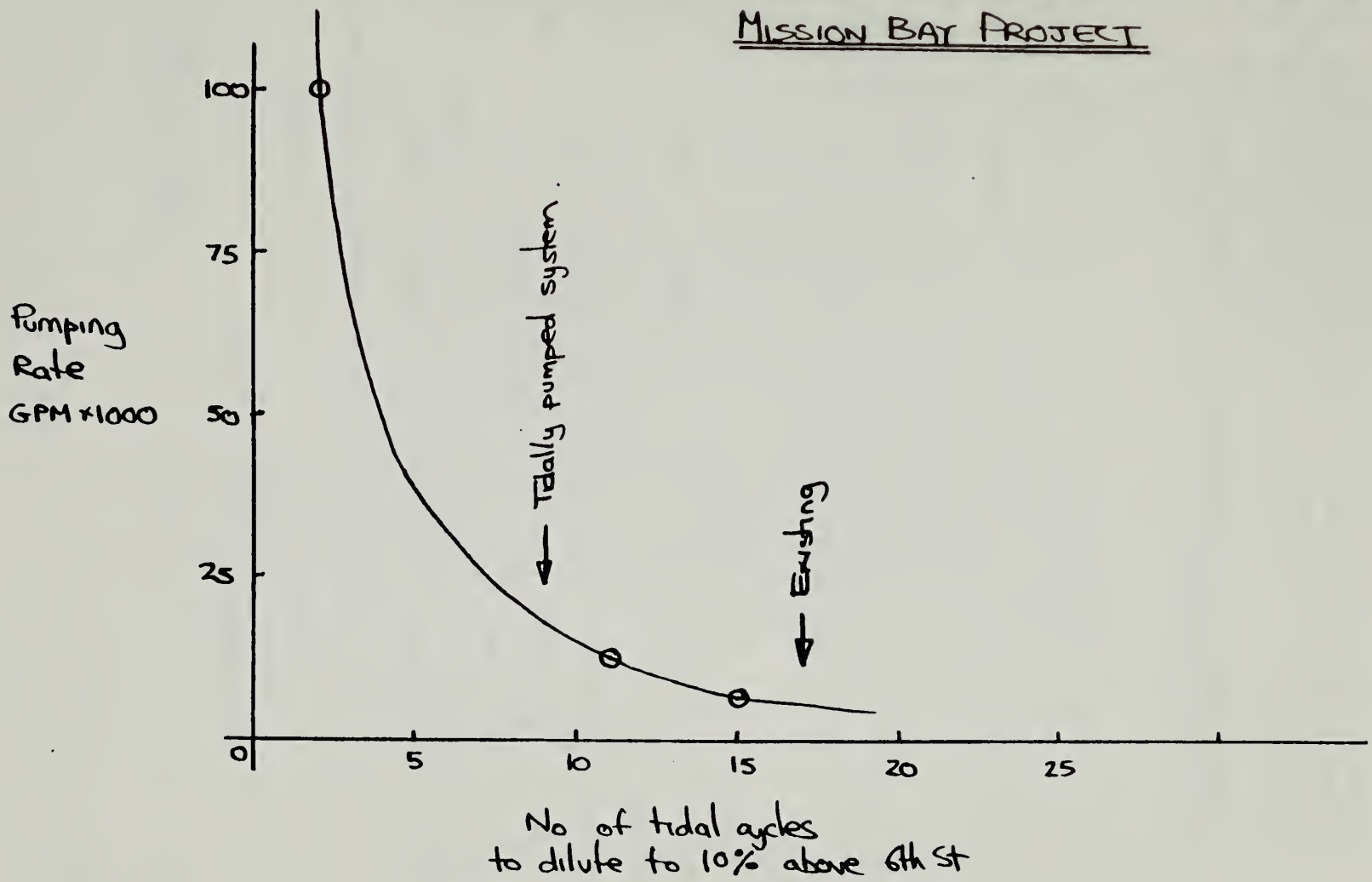

SEGMENT 1 : DEAD END OF CHANNEL TO 6 TH STREET
SEGMENT 2 : 6 TH STREET TO 5 TH STREET
SEGMENT 3 : 5 TH STREET TO 4 TH STREET
SEGMENT 4 : 4 TH STREET TO 3 RD STREET
CONCENTRATION
100
90
80
70
60
50
40
30
20
10
0
TIDAL CYCLE → 0 4 8 12 16 20 24 28 32 36 40 44 48 52 56 60 64
DAYS → 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

FIG. 3 DISPERSION RATE FOR EXISTING CONDITIONS

fig 4.

PUMPING RATE / DISPERSION TIME

MISSION BAY PROJECT



FBW
2/24/86

Hazards from High Water

Elevation can be stated relative to several datum planes. These include the Mean Lower Low Water datum (MLLW), the Mean Sea Level datum of 1929 (NGVD), the San Francisco City Plane datum, and the datum used by KCA Engineers for its maps of the Mission Bay site.

Several high water elevations are listed below, relative to different datum planes.

AT CHINA BASIN	ELEVATIONS (IN FEET)			
	MLLW DATUM	NGVD DATUM	S.F. CITY DATUM	KCA ENGR DATUM
MLLW	0.0	-3.0	-11.6	88.4
0.0 NGVD	+3.0	0.0	-8.6	91.4
MEAN TIDE LEVEL	+3.4	+0.4	-8.2	91.8
MHHW	+6.3	+3.3	-5.3	94.7
100 YEAR TSUNAMI	+7.8	+4.8	-3.8	96.2
100 YEAR HIGH TIDE	+9.6	+6.6	-2.0	98.0
0.0 S.F. CITY PLANE	+11.6	+8.6	0.0	100.0
TYPICAL GROUND SURFACE AT SITE	+8.6 TO +14.6	+5.6 TO +11.6	-3 TO +3	97 TO 103

500 YEAR TSUNAMI = +8.0 NGVD

BCDC JURISDICTION (HIGHEST TIDE) = +5.7 NGVD

TIDAL RANGES:

MLLW TO MHHW = 6.3 FT.

MLW TO MHW = 4.6 FT.

TABLE 1 TIDAL CHARACTERISTICS AT MISSION CREEK

TABLE 2

PRELIMINARY CIRCULATION ANALYSIS - MISSION CREEK

Run No.	Tidal Range ft	Channel Depth ft	Tidal Prism (1&2)	Tidal Circ. System	Pumped System	Pumped Flowrate gpm.	Inflow Volume ac-ft.	Dilution (Tidal Cycles) 10%	Dilution (Tidal Cycles) 1%
1	3	Existing	Existing	-	-	-	210	17	31
2	4.6	Existing	Existing	-	-	-	210	12	19
3	7.0	Existing	Existing	-	-	-	50	3	8
4	3	Existing	Doubled	-	-	-	210	11	20
5	3	Dredged	Doubled	-	-	-	210	16	30
6	3	Dredged	Existing	-	-	-	210	28	51
7	3	Existing	Existing	Seg 1	-	-	210	9[b]	>15[b]
8	3	Dredged	Existing	Seg 1	-	-	210	11[a]	>21[a]
9	3	Existing	Existing	Seg 2	-	-	210	11	20
10	3	Dredged	Existing	Seg 2	-	-	210	19	35
11	3	Existing	Existing	-	Seg 1	6,237	210	15[b]	>28[b]
12	3	Existing	Existing	-	Seg 1	12,474	210	11[b]	>20[b]
13	3	Existing	Existing	-	Seg 1	100,000	210	2	3

Notes

a) segment 2 value
b) segment 3 value

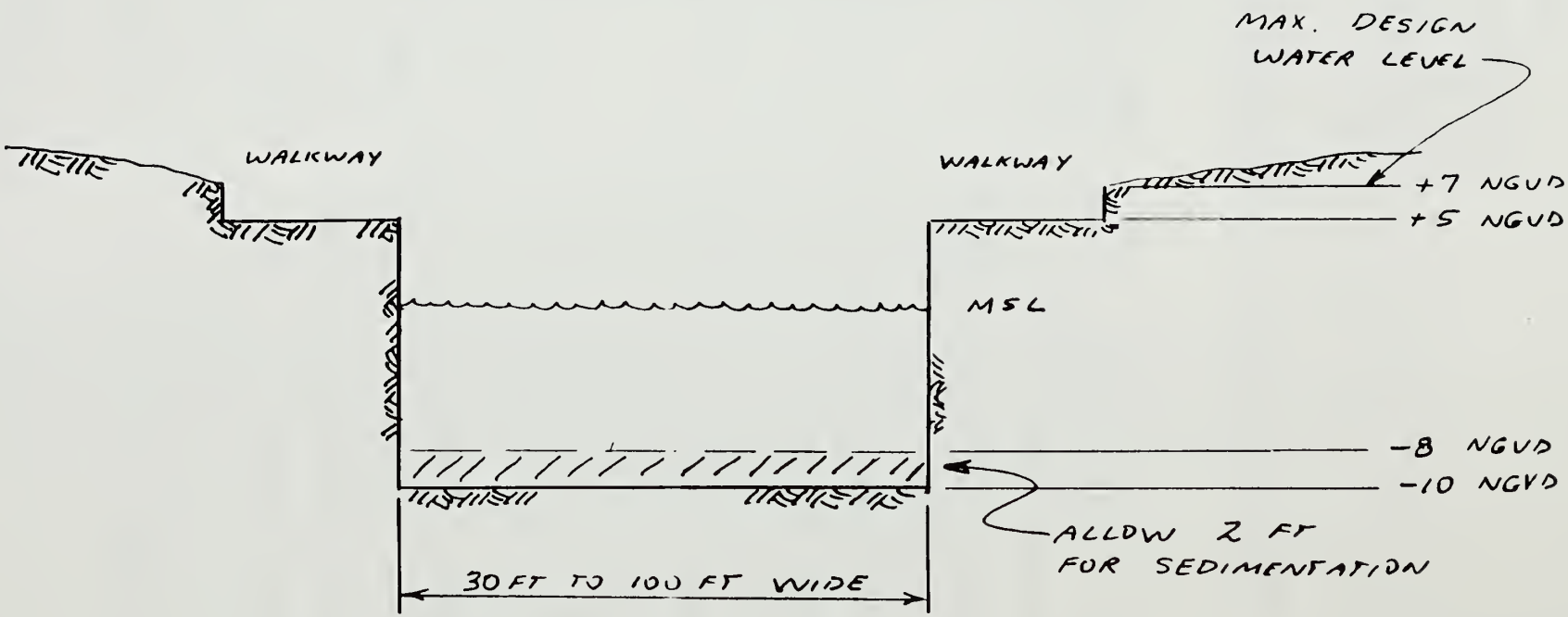


FIG. A1 CROSS SECTION THROUGH LOOPED CHANNEL

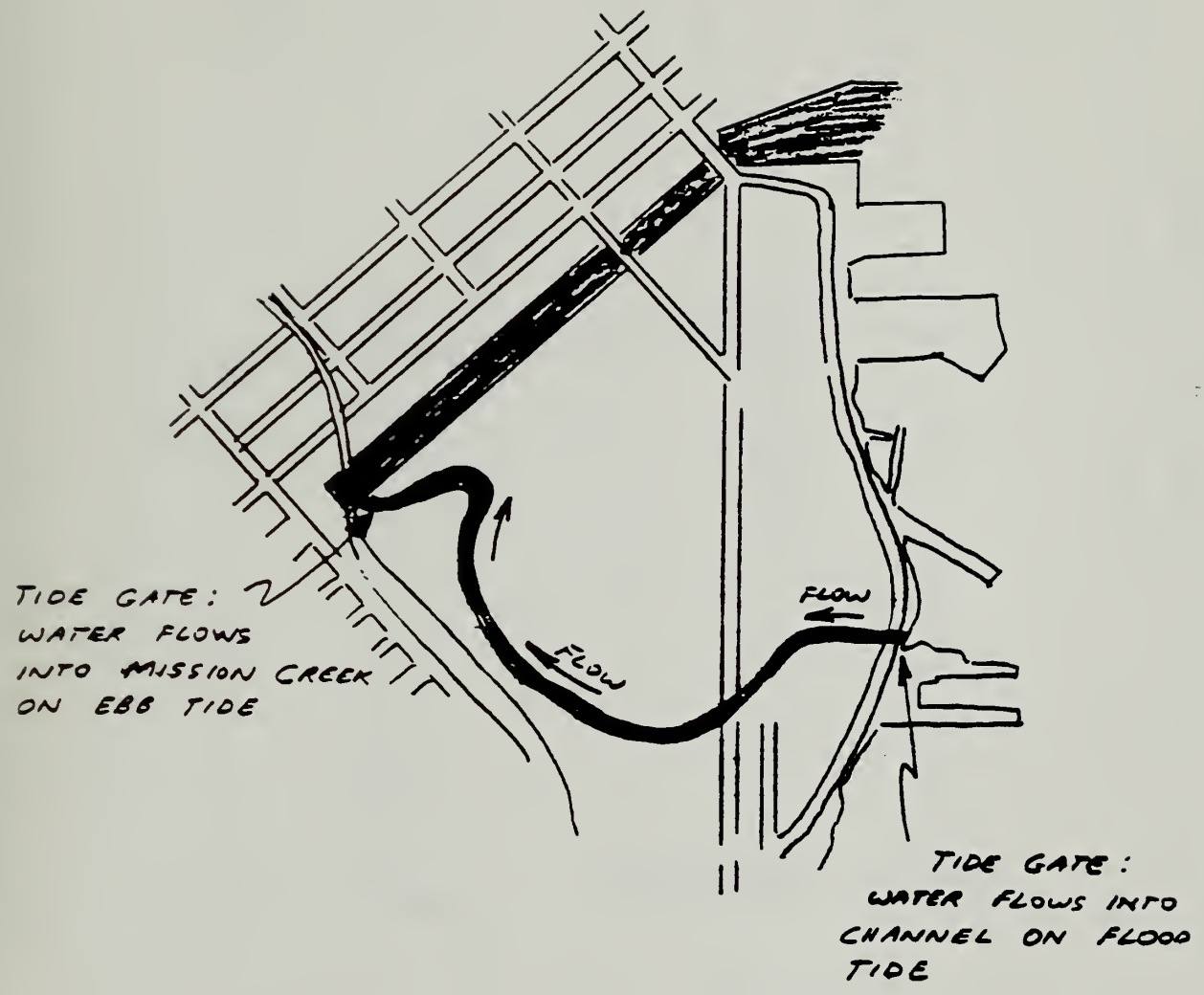


FIG. A2 LOOPED CHANNEL CONNECTED TO END OF MISSION CREEK

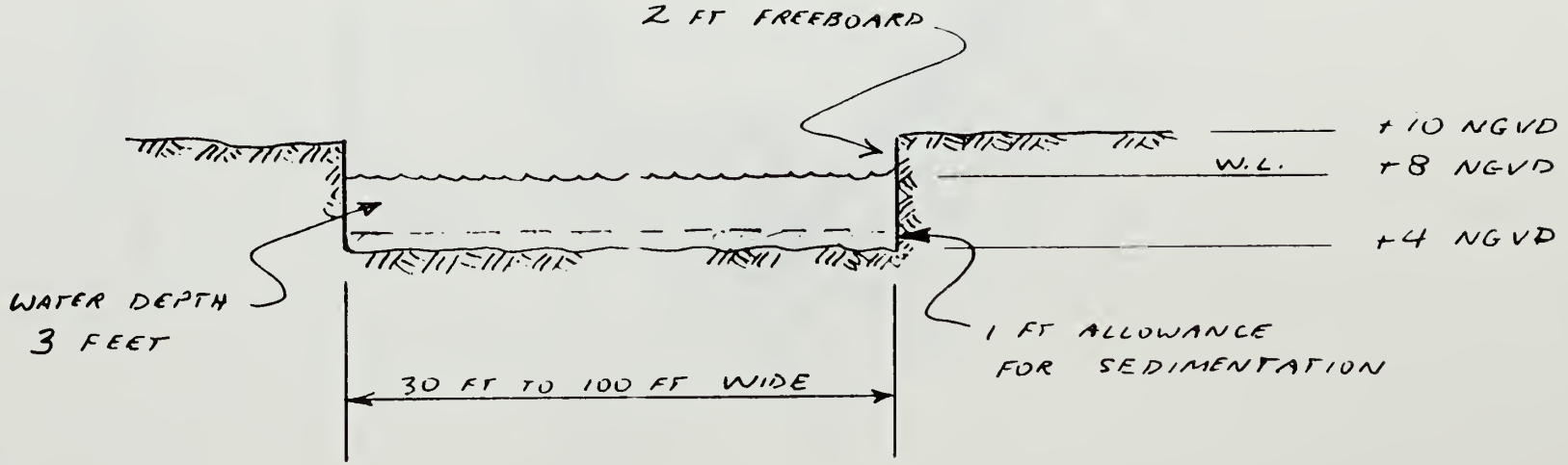


FIG. B1 ARTIFICIALLY PUMPED OPEN CHANNEL — LOW VELOCITY CONTINUOUS FLOW

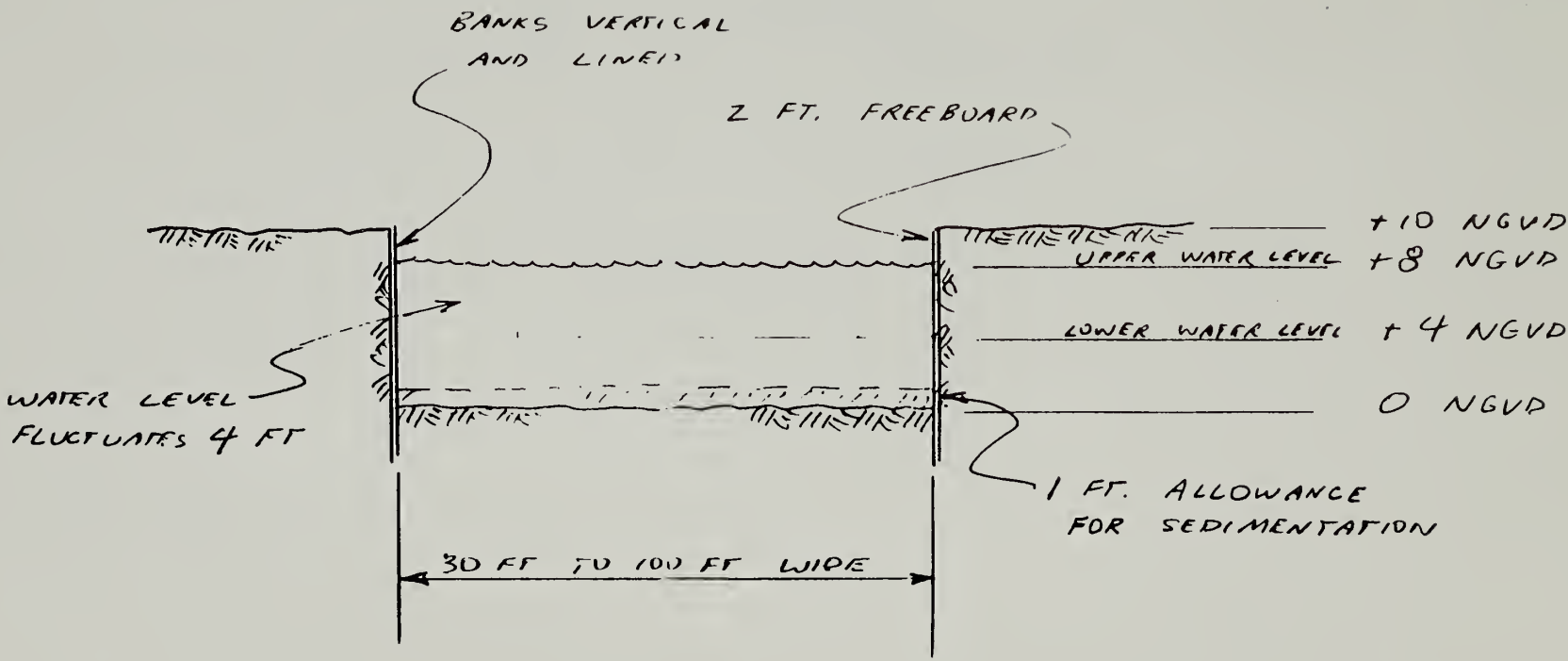

BANKS VERTICAL AND LINED
2 FT. FREEBOARD
+10 NGVD
UPPER WATER LEVEL +8 NGVD
LOWER WATER LEVEL +4 NGVD
0 NGVD
WATER LEVEL FLUCTUATES 4 FT
1 FT. ALLOWANCE FOR SEDIMENTATION
30 FT TO 100 FT WIDE

FIG. B2 ARTIFICIALLY PUMPED OPEN CHANNEL — LOW VELOCITY VARYING FLOW

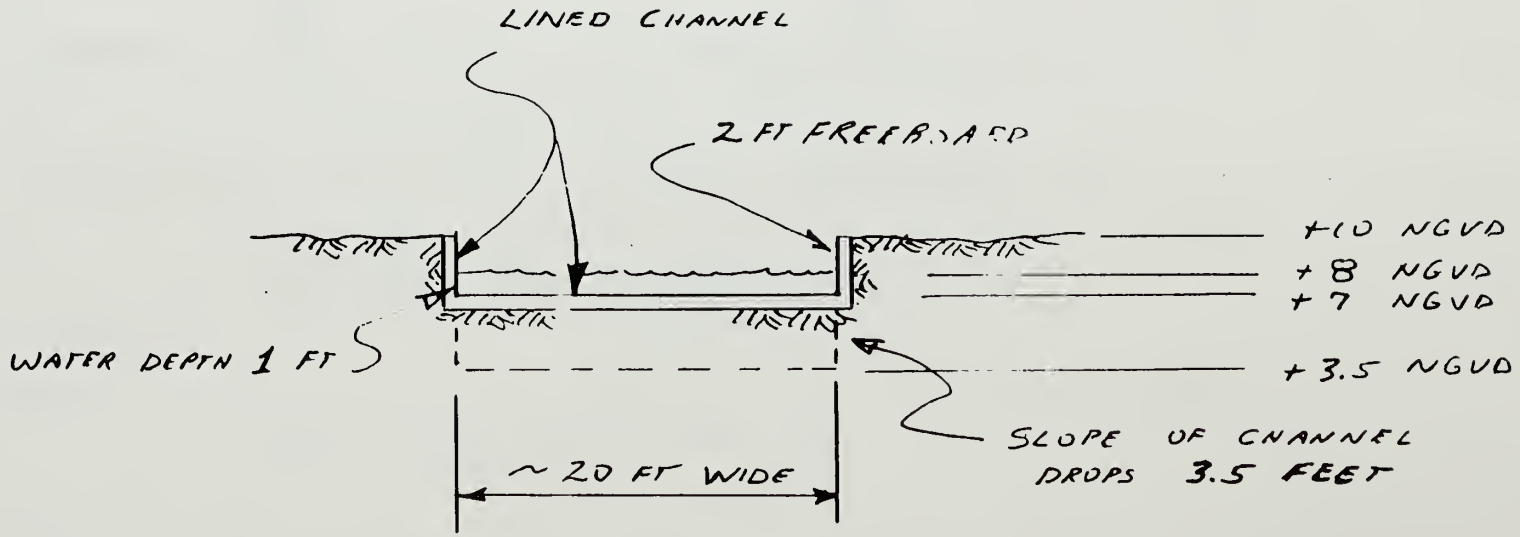


FIG. B3 ARTIFICIALLY PUMPED OPEN CHANNEL — HIGH VELOCITY CONTINUOUS FLOW